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MATHÉMATIQUES

SUR UNE CERTAINE CLASSE D'ÉQUATIONS INTÉGRALES SINGULIÈRES

Par S. MICHLIN

(Présenté par S. L. Soboleff, de l'Académie, le 15.VI.1939)

Le but de cette Note est de donner la solution du problème d'équivalence ([1,2]) pour les équations contenant les valeurs principales des intégrales du type de Cauchy. On peut réduire une telle équation à la forme suivante

$$\varphi(x) - \frac{\lambda b(x)}{\pi} \int_c \frac{\varphi(y)}{y-x} dy = f(x). \qquad (1)$$

Supposons que $b(x)$ satisfasse à la condition de Lipschitz et que c soit un contour simple fermé dont la courbure satisfait à la condition de Hölder. Or, le premier membre de (1) est un opérateur linéaire dans l'espace L_2. Nous désignons par $f(x)$ la somme d'une fonction connue appartenant à L_2 et d'un opérateur totalement continu dans L_2. Enfin, par λ nous désignons un paramètre numérique.

Traçons dans le plan complexe λ les courbes

$$\lambda = \pm \frac{i}{b(x)}. \qquad (2)$$

Ces courbes découpent le plan en domaines. On peut obtenir trois espèces différentes de ces domaines; le domaine D_0, qui contient le point $\lambda = 0$, le domaine D_∞, qui contient le point $\lambda = \infty$, et les domaines $D^{(n)}$ qui ne contiennent ni $\lambda = 0$, ni $\lambda = \infty$ ([1,2]). Le domaine D_0, ainsi que D_∞, est symétrique par rapport à l'origine. A chaque domaine $D^{(n)}$ correspond un certain domaine $D^{(n')}$, qui est symétrique à D par rapport à l'origine.

Nous avons démontré ([1,2]) que l'équation (1) est équivalente à une certaine équation de Fredholm si $\lambda \in D_0$ ou $\lambda \in D_\infty$. Ici nous allons donner des conditions nécessaires et suffisantes pour qu'il existe une telle équation de Fredholm, quand $\lambda \in D^{(n)}$.

Posons

$$m = \frac{1}{2\pi i} \int_c d \ln \frac{1 + i\lambda b(x)}{1 - i\lambda b(x)}. \qquad (3)$$

Le nombre entier m reste constant dans chacun des domaines D. Dans les domaines D_0 et D_∞ $m = 0$.

Lemme. *Admettons que $L\varphi$ soit un opérateur linéaire dans L_2. Supposons qu'il existe un opérateur linéaire M tel que l'equation*

$$ML\varphi = MF \tag{4}$$

est une équation de Fredholm équivalente à l'équation (5) *quelle que soit F.*

$$L\varphi = F \tag{5}$$

Or, le nombre des solutions linéairement indépendantes de l'équation $L\varphi = 0$ n'est pas inférieur à celui de l'équation $\overline{L}\omega = 0$, où $\overline{L}$ désigne l'opérateur adjoint à L.

1. Si l'équation (5) admet une solution, F est orthogonal aux solutions de l'équation $\overline{L}\omega = 0$. En effet

$$(F, \omega) = (L\varphi, \omega) = (\varphi, \overline{L}\omega) = 0.$$

2. Désignons par $\varphi_k\,(k = 1, 2 \ldots n)$ les solutions linéairement indépendantes de l'équation $L\varphi = 0$ et par $\psi_k\,(k = 1, 2 \ldots n)$ les mêmes solutions de l'équation $\overline{(ML)}\psi = \overline{L}\overline{M}\psi = 0$. Pour que l'équation (4) ou (5) admette une solution, il faut et il suffit que

$$(MF, \psi_k) = (F, \overline{M}\psi_k) = 0. \tag{6}$$

Notons que $\overline{M}\psi_k = \varphi_k$ sont des solutions de l'équation $\overline{L}\omega = 0$.

3. L'équation $\overline{L}\omega = 0$ n'a pas de solutions qui sont linéairement indépendantes avec φ_k. Si l'on a

$$\overline{L}\omega_0 = 0, \quad (\omega_0, \overline{\varphi_k}) = 0, \quad \omega_0 \not\equiv 0,$$

l'équation

$$L\varphi = \omega_0$$

admet une solution d'après n°2 et n'admet pas de solutions d'après n°1.

Théorème. *Pour que l'équation* (1) *soit équivalente à une certaine équation de Fredholm, il faut et il suffit que m soit non-négatif.*

Soit $m = 0$. En suivant la méthode de M. Carleman [3] nous obtenons:

$$\varphi(x) = \frac{f(x)}{1 + \lambda^2 b^2(x)} + \frac{\lambda e^{\omega(x)} b(x)}{\pi \sqrt{1 + \lambda^2 b^2(x)}} \int_c \frac{e^{-\omega(y)} f(y)}{\sqrt{1 + \lambda^2 b^2(y)}} \frac{dy}{y - x}, \tag{7}$$

où

$$\omega(x) = \frac{1}{2\pi i} \int_c \ln \frac{1 + i\lambda b(y)}{1 - i\lambda b(y)} \frac{dy}{y - x}. \tag{8}$$

Soit maintenant $m \neq 0$. On peut supposer que c est la circonférence $|z| = 1$. On peut l'obtenir par un changement des variables assez simple. On peut poser

$$\ln \frac{1 + i\lambda b(x)}{1 - i\lambda b(x)} = \theta(x) + m \ln x, \tag{9}$$

où $\theta(x)$ satisfait à la condition de Lipschitz sur c. Posons encore

$$\psi(z) = \frac{1}{2\pi i} \int_c \frac{\theta(y)}{y - z}\, dy, \tag{10}$$

où z est un point arbitraire qui n'appartient pas à c. Désignons par les indices i et e respectivement les valeurs limites intérieures et extérieures d'une fonction quelconque.

Or

$$e^{\psi_i(x)} = e^{\psi_e(x)}\, e^{\vartheta(x)}. \tag{11}$$

Notons que $e^{\psi(z)}$ ne s'annulle pas. Considérons l'équation homogène

$$\varphi(x) - \frac{\lambda b(x)}{\pi} \int_c \frac{\varphi(y)}{y-x}\, dy = 0. \tag{12}$$

Posons d'après M. Carleman [3]

$$\frac{1}{2\pi i} \int_c \frac{\varphi(y)}{y-z}\, dy = F(z)\, e^{\psi(z)}. \tag{13}$$

Alors on obtient

$$F_i(x) - x^m F_e(x) = 0. \tag{14}$$

Sur la circonférence c on a

$$F_i(x) = \sum_{k=0}^{\infty} a_k x^k, \quad F_e(x) = \sum_{k=-1}^{-\infty} a_k x^k. \tag{15}$$

Substituons (15) dans (14). Alors nous trouverons facilement le résultat suivant; quand $m < 0$, l'équation (12) n'a qu'une solution triviale; quand $m > 0$, la même équation a m solutions linéairement indépendantes.

On peut réduire l'équation adjointe à (12) à la suivante

$$\psi(x) + \frac{\lambda b(x)}{\pi} \int_c \frac{\psi(y)}{y-x}\, dy = 0. \tag{16}$$

En notant que m change de signe avec λ et en utilisant le lemme on peut conclure: si $m < 0$, l'équation (12) n'est pas équivalente à une équation de Fredholm.

Si $m > 0$, l'équation (16) n'a qu'une solution triviale. En appliquant aux deux membres de l'équation (1) l'opérateur du premier membre de (16), nous obtiendrons une équation équivalente à (1). Il suit de la formule de Poincaré-Bertrand [4]

$$\frac{1}{\pi^2} \int_c \frac{dt}{t-y} \int_c \frac{\varphi(y)}{y-x}\, dy = -\varphi(x) \tag{17}$$

que l'équation ainsi obtenue est une équation de Fredholm. Ainsi quand $m > 0$, l'équation (1) est équivalente à une équation de Fredholm.

Considérons maintenant deux domaines $D^{(n)}$ symétriques par rapport à l'origine. L'équation (1) est équivalente à une équation de Fredholm dans les deux domaines (quand $m = 0$) ou bien elle est équivalente à une équation de Fredholm dans l'un de ces domaines et n'est pas équivalente dans l'autre (quand $m \neq 0$).

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MATHÉMATIQUES

SUR LE PROCÉDÉ D'INTERPOLATION DE FEJÉR

Par S. LOSINSKY

(Présenté par S. N. Bernstein, de l'Académie, le 2. V. 1939)

1. Soit $f(x)$ une fonction réelle et continue de la variable réelle x, définie sur l'intervalle $-1 \leqq x \leqq 1$. Désignons par $x_1^{(n)}, x_2^{(n)}, \ldots x_n^{(n)}$ les zéros du n-ième polynôme de Tschebycheff $T_n(x) = \cos(n \arccos x)$ et par $L_n(x) = L_n(f; x)$ le polynôme d'interpolation de Lagrange d'ordre $\leqq n-1$, qui satisfait aux conditions:

$$L_n(x_k^{(n)}) = f(x_k^{(n)}) \qquad (k = 1, 2, \ldots n). \tag{1}$$

Désignons par $\bar{L}_n(x) = \bar{L}_n(f; x)$ le polynôme d'interpolation d'Hermite d'ordre $\leqq 2n-1$ qui satisfait aux conditions

$$\bar{L}_n(x_k^{(n)}) = f(x_k^{(n)}) \qquad (k = 1, 2, \ldots n) \tag{2}$$

$$\bar{L}_n'(x_k^{(n)}) = 0 \qquad (k = 1, 2, \ldots n). \tag{3}$$

Les polynômes $L_n(x)$ et $\bar{L}_n(x)$ sont définis d'une façon univoque.
Il est connu que l'égalité

$$\lim_{n\to\infty} L_n(x) = f(x) \qquad (-1 \leqq x \leqq 1) \tag{4}$$

n'a pas lieu en général, mais que

$$\lim_{n\to\infty} \bar{L}_n(x) = f(x) \tag{5}$$

uniformément pour $-1 \leqq x \leqq 1$.

La relation (5) a été prouvée par Fejér (1).

2. Soit $f(z)$ une fonction régulière dans $|z| < 1$, continue dans $|z| \leqq 1$; désignons par $z_1, z_2 \ldots z_n$ les racines d'ordre n de 1:

$$z_s = e^{\frac{2\pi i s}{n}} \qquad (s = 1, 2, \ldots n). \tag{6}$$

Soient $L_n(z) = L_n(f; z)$ le polynôme de Lagrange, d'ordre $\leqq n-1$ satisfaisant aux conditions

$$L_n(z_s) = f(z_s) \qquad (s = 1, 2, \ldots n) \tag{7}$$

et $\overline{L}_n(z) = \overline{L}_n(f; z)$ le polynôme d'Hermite d'ordre $\leqq 2n-1$, satisfaisant aux conditions

$$\overline{L}_n(z_s) = f(z_s) \qquad (s = 1, 2, \ldots n) \tag{8}$$

$$\overline{L}'_n(z_s) = 0 \qquad (s = 1, 2, \ldots n). \tag{9}$$

On sait que

$$\lim_{n\to\infty} L_n(z) = f(z) \quad \text{pour} \quad |z| < 1 \tag{10}$$

et la convergence est uniforme dans $|z| \leqq \rho$ pour tout $\rho < 1$. On sait aussi qu'en général pour $|z| = 1$ la relation

$$\lim_{n\to\infty} L_n(z) = f(z)$$

n'a pas lieu [Fejér (²)].

Par analogie avec le résultat de Fejér précédemment cité et concernant l'intervalle réel on pourrait croire que

$$\lim_{n\to\infty} \overline{L}_n(z) = f(z)$$

uniformément pour $|z| \leqq 1$. Nous allons démontrer qu'il n'en est pas ainsi; en effet on a le théorème suivant.

Théorème. *Soit k un entier, $k \geqq 2$, $f(z)$ une fonction régulière dans $|z| < 1$ continue pour $|z| \leqq 1$. Désignons par $\overline{L}_n(z) = \overline{L}_n(f; z)$ le polynôme unique d'ordre $\leqq kn-1$ qui satisfait aux conditions*

$$\overline{L}_n(z_s) = f(z_s) \qquad (s = 1, 2, \ldots n) \tag{11}$$

$$\overline{L}_n^{(m)}(z) = 0 \qquad (s = 1, 2, \ldots n;\ m = 1, 2, \ldots k-1). \tag{12}$$

Alors

$$\lim_{n\to\infty} \overline{L}_n(z) = f(z) \quad \text{pour} \quad |z| < 1$$

et la convergence est uniforme pour $|z| \leqq \rho < 1$. Pour $|z| = 1$ la suite $\overline{L}_n(z)$ peut être divergente.

3. La démonstration de ce théorème est basée sur quelques évaluations asymptotiques que nous indiquerons sans les démontrer.

Posons

$$\varphi_n(z) = \frac{1}{1 + z + \cdots + z^{n-1}}. \tag{13}$$

Alors

$$\left[\frac{d^m}{dz^m}\{\varphi_n(z)\}^k\right]_{z=1} = 0\left[\left(\frac{1}{n}\right)^{k-m}\right] \quad (m = 0, 1, 2, \ldots k-2) \tag{14}$$

$$\left[\frac{d^{k-1}}{dz^{k-1}}\{\varphi_n(z)\}^k\right]_{z=1} = \frac{(-1)^{k-1}}{n}(k-1)! + 0\left(\frac{1}{n^2}\right). \tag{15}$$

On trouve encore

$$\sum_{s=1}^{n}\left|\frac{z^n - 1}{z - z_s}\right|^p \leqq \frac{1}{2}\pi^2 n^p \quad (p \text{ entier} \geqq 2;\ |z| \leqq 1). \tag{16}$$

Le polynôme $\overline{L}_n(z)$ dont il s'agit dans le théorème peut être écrit ainsi

$$\overline{L}_n(z)=\sum_{s=1}^{n}\left(\frac{z^n-1}{z-z_s}\right)^k\left\{\left(\frac{z-z_s}{z^n-1}\right)^k_{z=z_s}+\frac{1}{1}!\left[\frac{d}{dz}\left(\frac{z-z_s}{z^n-1}\right)^k\right]_{z=z_s}(z-z_s)+\right.$$

$$\left.+\ldots+\frac{1}{(k-1)!}\left[\frac{d^{k-1}}{dz^{k-1}}\left(\frac{z-z_s}{z^n-1}\right)^k\cdot\right]_{z=z_s}(z-z_s)^{k-1}\right\}f(z_s). \qquad (17)$$

A l'aide de (14) on trouve

$$\sum_{s=1}^{n}\left|\left(\frac{z^n-1}{z-z_s}\right)^k\left[\frac{d^m}{dz^m}\left(\frac{z-z_s}{z^n-1}\right)^k\right]_{z=z_s}(z-z_s)^m\right|=$$

$$=\frac{1}{(1-|z|)^{k-m}}\,0\left[\left(\frac{1}{n}\right)^{k-m-1}\right]. \qquad (18)$$

$$(m=0,1,\ldots k-2).$$

L'affirmation du théorème quant à la convergence de $\overline{L}_n(z)$ pour $|z|<1$ résulte de (18) et de (15). A l'aide de (16) on peut écrire

$$\overline{L}_n(z)=0(1)+(1-z^n)^{k-1}L_n(z). \qquad (19)$$

Ici $0(1)$ ne surpasse pas en module une constante fixe pour tout n et z, $|z|\leqq 1$. Cette constante ne dépend que de $\max_{|z|\leqq 1}|f(z)|$.

4. On peut [Fejér (2)] construire une fonction $f(z)$, régulière dans $|z|<1$ continue pour $|z|\leqq 1$ et telle que

$$\lim_{n\to\infty}|L_{3n^3}(f;-1)|=+\infty.$$

De (19) on tire que pour une fonction pareille

$$\lim_{n\to\infty}|\overline{L}_{3n^3}(f;-1)|=+\infty$$

c'eat-à-dire que la suite des polynômes $\overline{L}^n(f;z)$ est divergente pour $z=-1$. Le théorème est démontré.

5. Il est intéressant de savoir dans quels cas la suite $L_n(f;z)$ converge uniformément vers $f(z)$ dans $|z|\leqq 1$. Nous allons indiquer ici quelques résultats dont le premier est connu.

Soit $f(z)$ une fonction régulière dans $|z|<1$, continue pour $|z|\leqq 1$. Chaque des conditions suivantes est suffisante pour la convergence uniforme de $L_n(f;z)$ vers $f(z)$ dans $|z|\leqq 1$.

1°. $f(z)$ satisfait à la condition de Lipschitz d'ordre $\alpha>0$ pour $|z|=1$. Il suffit même que $f(z)$ satisfait à la condition de Dini, c'est-à-dire que

$$\lim_{\delta\to+0}\omega(\delta)\log\frac{1}{\delta}=0$$

où $\omega(\delta)$ est le module de continuité de $F(\vartheta)=f(e^{i\vartheta})$.

2°. $\sum_{n=0}^{\infty}|c_n|<+\infty$ où $\sum_{n=0}^{\infty}c_nz^n$ est le développement de Maclaurin de $f(z)$. Une proposition analogue appartient à Marcinkiewicz (4). La démonstration est très simple.

Soit $Q(z)$ un polynôme quelconque d'ordre $\leqq n-1$. Il est clair que

$$L_n(z^{\nu n}Q;\, z) \equiv L_n(Q,\, z) \equiv Q(z) \quad (\nu \geqq 0 \text{ est un entier}) \tag{20}$$

car dans les points d'interpolation z_s les polynômes $z^{\nu n}Q(z)$ et $Q(z)$ sont égaux. Posons

$$Q_\nu(z) = c_{\nu n} + c_{\nu n+1}z + \ldots + c_{(\nu+1)n-1}z^{n-1} \quad (\nu = 0,\, 1,\, 2\ldots).$$

Il est évident que

$$f(z) = \sum_{\nu=0}^{\infty} z^{\nu n}Q_\nu(z). \tag{21}$$

De (20) et (21) on tire

$$L_n(f;\, z) = L_n\Big(\sum_{\nu=0}^{\infty} z^{\nu n}Q_\nu;\, z\Big) = \sum_{\nu=0}^{\infty} L_n(z^{\nu n}Q_\nu;\, z) = \sum_{\nu=0}^{\infty} Q_\nu(z).$$

Alors

$$|L_n(f;\, z) - f(z)| = \Big|\sum_{k=n}^{\infty} c_k z^k - \sum_{\nu=1}^{\infty} Q_\nu(z)\Big| \leqq \Big|\sum_{k=n}^{\infty} c_k z^k\Big| +$$

$$+ \Big|\sum_{\nu=1}^{\infty} Q_\nu(z)\Big| \leqq 2\sum_{k=n}^{\infty} |c_k| \to 0 \qquad \text{c. q. f. d.}$$

3^0. $f(z)$ est absolument continue sur la circonférence $|z| = 1$. La série de Maclaurin de la fonction $f(z)$ est alors absolument convergente pour $|z| \leqq 1$ [Hardy et Littlewood (3)]; l'affirmation résulte donc de 2^0. La condition 3^0 est, en particulier, remplie si $f(z)$ effectue la représentation conforme de $|z| < 1$ sur une aire plane limitée par une courbe de Jordan rectifiable.

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MATHÉMATIQUES

SUR LES LOIS ASYMPTOTIQUES DE LA DISTRIBUTION DES RACINES RÉELLES DES INTÉGRALES OSCILLATOIRES D'UNE ÉQUATION DIFFÉRENTIELLE LINÉAIRE DU SECOND ORDRE

Par T. SARYMSAKOFF

(Présenté par S. N. Bernstein, de l'Académie, le 28. V. 1939)

Dans la présente Note en profitant d'une idée empruntée à la théorie des probabilités j'indique une loi asymptotique pour la distribution des racines réelles des intégrales oscillatoires d'une équation différentielle linéaire du second ordre. Nous verrons dans la suite que les lois de distribution ici considérées sont plutôt de caractère statistique (et n'embrassent que le cas de la dimension égale à un) tandis que la plupart des distributions considérées par d'autres auteurs était, il paraît, de caractère localement géométrique. Pour déduire la loi de distribution des racines on s'appuie essentiellement sur un théorème qui est une précision du théorème bien connu de Sturm dans la théorie des équations linéaires du second ordre. On considère, comme exemples, les équations différentielles du second ordre auxquelles satisfont les polynômes classiques de Tschebycheff, de Legendre, d'Hermite et de Laguerre. Je signalerai encore que les lois de distribution des racines de ces polynômes ont été déjà obtenues dans un travail que je n'ai pas encore fait publier; mais j'employais alors une méthode différente — celle des courbes de distribution de K. Pearson. L'idée de l'application de cette méthode appartient à mon maître, V. Romanovsky. Cependant je dois indiquer qu'une série de travaux d'autres auteurs a aussi été consacrée à l'étude des racines des polynômes indiqués, par exemple, ceux de O. Bottem (1), Zernuke (2), Webster (3), Spenser (4) et d'autres.

Indiquons maintenant une précision du théorème de Sturm.

Théorème 1. *Si les racines des intégrales des équations*

$$y'' + a^2 y = 0, \tag{1}$$

$$z'' + b^2 z = 0, \tag{2}$$

où

$$b > a > 0$$

se séparent mutuellement dans un certain intervalle et si l'on a l'équation

$$u'' + \varphi(x)\, u = 0 \tag{3}$$

où

a) $a^2 \leqslant \varphi(x) \leqslant b^2$ *pour* $\alpha \leqslant x \leqslant \beta$

b) $\varphi(x)$ *est continue dans* (α, β)

alors les racines d'une intégrale quelconque de (3) *séparent celles des intégrales des équations* (1) *et* (2) *dans* $(\alpha \leqslant x \leqslant \beta)$ *sauf peut être un intervalle entre deux racines consécutives d'une intégrale de* (1) *qui contient deux racines d'une intégrale de* (3).

Corollaire. On a la relation suivante: $r = q + \varepsilon$ où r est le nombre des racines d'une intégrale quelconque de (3) dans (α, β), q est le nombre des racines d'une intégrale quelconque de (2) dans le même intervalle et ε est égal à l'un des nombres -1, 0, $+1$.

Nous indiquons ici ce corollaire car nous en aurons besoin pour la démonstration du théorème qui suit.

Appelons la limite double

$$\psi(t) = \lim_{\Delta t \to 0} \frac{1}{\Delta t} \lim_{n \to \infty} \frac{N_n(t, t + \Delta t)}{n} \tag{4}$$

loi de distribution des racines d'une intégrale de l'équation (3), où n signifie le nombre des racines d'une intégrale de l'équation (3) et $N_n(t, t + \Delta t)$ est le nombre des racines de cette même intégrale dans l'intervalle $(t, t + \Delta t)$.

Nous aurons alors le

Théorème 2. *Si dans un certain intervalle fini* (a, b)* *le nombre des racines réelles d'une intégrale quelconque de l'équation* (3) *est assez grand et si la fonction* $\varphi(x)$ *est continue et positive dans* (a, b), *alors la loi asymptotique de la distribution de ces racines dans l'intervalle* (a, b) *est donnée par la formule*

$$\psi(x) = \frac{1}{\pi n} \sqrt{\varphi(x)} \tag{5}$$

où n *est le nombre des racines d'une intégrale de* (3) *dans* (a, b).

Démonstration. Supposons $b > a > 0$ ce qui ne restreint pas la généralité de la démonstration. Formons ensuite les équations

$$u'' + \varphi(\alpha) u = 0 \tag{6}$$

$$u'' + \varphi(\beta) u = 0, \tag{7}$$

$$a \leqslant \alpha < \beta \leqslant b$$

et considérons le cas où la fonction $\varphi(x)$ croît constamment dans l'intervalle (α, β). Choisissons ensuite les nombres α et β de telle façon que les racines des intégrales des équations (6) et (7) se séparent mutuellement dans l'intervalle (α, β).

La possibilité de construire des équations (6) et (7) vérifiant ces conditions suit de la continuité de la fonction $\varphi(x)$ et de ce que les nombres α et β sont arbitraires.

En vertu de ce que la fonction $\varphi(x)$ croît constamment dans l'intervalle (α, β), nous avons

$$\varphi(\alpha) \leqslant \varphi(x) \leqslant \varphi(\beta) \quad \text{pour} \quad \alpha \leqslant x \leqslant \beta.$$

Maintenant, en appliquant le théorème 1 et son corrollaire aux équations (3), (6) et (7) il est facile à déterminer par un calcul simple le nombre des racines d'une intégrale de l'équation (3) dans l'intervalle (α, β). En désignant ce nombre par $N_n(\alpha, \beta)$ nous aurons

$$N_n(\alpha, \beta) = \left[\frac{\beta - \alpha}{\pi} \sqrt{\varphi(\beta)}\right] + \varepsilon^{**} \tag{8}$$

où ε prend l'une des valeurs: $-1, 0, 1, 2$.

---

* Remarquons que les extrêmités de l'intervalle peuvent dans certains cas varier suivant le nombre des racines situées dans (a, b).

** $[x]$ désigne le plus grand entier qui ne surpasse pas x.

Il reste à déterminer la limite double (4).

Posons à cet effet dans (8): $\alpha = x$, $\beta = x + \Delta x$; en faisant la substitution dans la double limite (4) nous aurons

$$y = \frac{1}{\pi n} \sqrt{\varphi(x)} \tag{5}$$

ce qu'il fallait démontrer.

Dans le cas où $\varphi(x)$ est une fonction décroissante, la démonstration est tout-à-fait la même, seulement dans ce cas le nombre $N_n(\alpha, \beta)$ sera égal à

$$\left[\frac{\beta - \alpha}{\pi} \sqrt{\varphi(\beta)}\right] + \varepsilon_1$$

où ε_1 prend l'une des valeurs suivantes: $-1, 0, 1, 2, 3$.

En appliquant ce théorème aux équations différentielles des polynômes de Tschebycheff, de Legendre, d'Hermite et de Laguerre nous obtenons la loi limite de distribution

$$\psi(x) = \frac{1}{\pi \sqrt{1 - x^2}} \qquad (-1 < x < 1) \tag{9}$$

des polynômes de Tschebycheff et de Legendre et les lois asymptotiques

$$\psi(x) = \frac{1}{\pi n} \sqrt{2n + 1 - x^2}, \left(-1 < \frac{x}{\sqrt{2n+1}} < 1\right), \tag{10}$$

$$\psi(x) = \frac{1}{\pi (2n+1)} \sqrt{\frac{4n+2}{x} - 1}, \left(0 < \frac{x}{4n+2} < 1\right) \tag{11}$$

pour les polynômes d'Hermite et de Laguerre respectivement.

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HYDRAULICS

ON THE CONTINUITY OF VARIATION OF THE VELOCITY HODOGRAPH IN A PLANE STEADY MOTION OF GROUND WATERS

By P. POLUBARINOVA-KOCHINA

(Communicated by N. I. Mouskhelishvili, Member of the Academy, 1.VI. 1939)

For the solution of problems concerning the motion of ground waters in earth dams it proves usually necessary to construct the velocity hodograph. Considering the finite number of possible cases at such a construction, as a rule one succeeds in determining the only possible configuration (1). However, if the velocity hodograph possesses incisions (Fig. 1 and 2), it is sometimes not quite clear which incision is to be taken. In one of the most complicated examples Davison [(1), p. 323] proposes in this direction some hypotheses without giving, however, a complete investigation of the problem. Using the idea of continuity, we consider in the present paper some examples of this character.

In an earth dam with inclined slopes the depth of the up-stream water is usually small in comparison with the length of the foundation of the dam and in this case the depression curve (the line of the free surface) has a turning point. It arises the question whether the turning point will remain on the depression curve when the level of the up-stream water raises, and if it does disappear, at a certain height of the water, what form the velocity hodograph will assume? In the simplest case of a drained dam on a water-tight foundation (Fig. 1) we obtain the following picture. For small values of $\frac{h}{l}$ we have a turning point B. The velocity hodograph is represented by the polygon $EDCBAE$. When $\frac{h}{l}$ increases, the point B approaches the point C and for some definite value of $\frac{h}{l}$ coincides with C. At a further increase of $\frac{h}{l}$ an increasing incision CB_1 arises, and for $\frac{h}{l} \to \infty$ the point B_1 tends to infinity. If we fix h and decrease l to zero, so that the point E of the dam tends to the point D, then in the limit case from the velocity hodograph there remains only the triangle $EACB_1$ while its upper part disappears.

For the motion considered in Fig. 1 it is not difficult to find the solution, if we use the known Kirchhoff's method (2). Suppose that the domain of motion is conformly mapped on the upper half-plane of a subsidiary complex variable t in such a way that the points E, A, B, C, D are respectively transformed into points $t = 0, a, b, 1, \infty$. Then for the complex co-ordinate $z = x + iy$ and the complex potential $f = \varphi + i\psi$ (φ is the velocity potential and ψ — the stream function) we obtain the following expressions in dependence of t:

$$z = C_1 \int_0^1 \int_0^t \frac{(b-t)\,dt}{(1-t)^{\frac{1}{2}+\alpha}\sqrt{t(a-t)}} \cdot \frac{1}{\sqrt{t(a-t)(1-t)}}\,dt + l, \tag{1}$$

$$f = C_2 \int_0^t \frac{dt}{\sqrt{t(a-t)(1-t)}} + C. \tag{2}$$

Herein $\alpha = \frac{\theta}{\pi}$, where θ is the angle between the slope and the foundation of the dam.

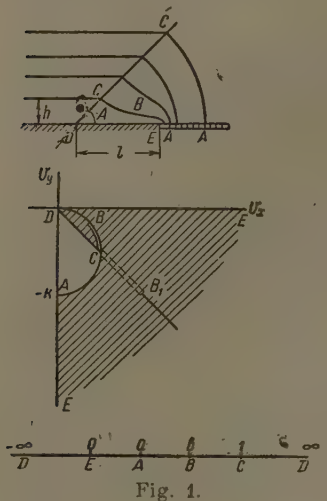

Fig. 1.

In the formulae for z and f we have four constants which are to be determined: C_1, C_2, a and b (C may be chosen arbitrarily).

For their determination we have the following equations:

$$C_1 \int_{\infty}^{0} F(t)\,dt = l, \tag{3}$$

$$C_1 \int_{1}^{\infty} F(t)\,dt = -h(\operatorname{cotg}\pi\alpha + i), \tag{4}$$

$$\frac{C_1}{C_2} \int_0^a \Phi(t)\,dt = -\frac{1}{k}, \tag{5}$$

$$\frac{C_1}{C_2} \int_0^1 \Phi(t)\,dt = \frac{1}{k}(\operatorname{tg}\pi\alpha - i), \tag{6}$$

where

$$F(t) = \frac{\int_0^1 \Phi(t)\,dt}{\sqrt{t(a-t)(1-t)}}, \qquad \Phi(t) = \frac{b-t}{(1-t)^{\frac{1}{2}+\alpha}\sqrt{t(a-t)}}.$$

These formulae are valid for $b < 1$ as well as for $b > 1$. In the case when the point B coincides with C, b becomes equal to 1, and we remain with three unknowns C_1, C_2 and a and four equations (3) – (6). Consequently, in this case between the parameters h, l and α (which we must, in general, consider as given) must exist a certain relation. Dividing (6) by (5) and cancelling the imaginary terms, we obtain the following equation:

$$\operatorname{tg}\pi\alpha = \frac{I_2}{I_1}, \tag{7}$$

where

$$I_1 = \int_0^a \frac{(1-t)^{\frac{1}{2}-\alpha}}{\sqrt{t(a-t)}}\,dt, \qquad I_2 = \int_a^1 \frac{(1-1)^{\frac{1}{2}-\alpha}}{\sqrt{t(t-a)}}\,dt.$$

From equation (7) we find, for a given α, a root a between 0 and 1, and substituting it into the formulae (3) and (4), divide (4) by (3). After some transformations we find

$$\frac{h}{l} = \frac{\sin\theta \int_1^{\infty} \frac{I_1 \sec\theta + \int_1^{t} \frac{(t-1)^{\frac{1}{2}-\alpha}}{\sqrt{t(t-a)}}\,dt}{\sqrt{t(t-a)(t-1)}}\,dt}{\int_{-\infty}^{0} \frac{\int_t^{0} \frac{(1-t)^{\frac{1}{2}-\alpha}}{\sqrt{|t|(t-a)}}\,dt}{\sqrt{|t|(a-t)(1-t)}}\,dt}. \quad (8)$$

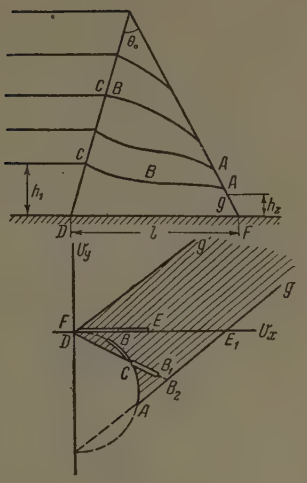

Fig. 2.

The equation (8) determines that value of $\frac{h}{l}$, at which the turning point disappears. In the Institute of Mathematics calculations according to the formulae (7) and (8) were carried out by M. D. Takhtamysheva for the values $\theta = \frac{\pi}{4}$ and $\theta = \frac{\pi}{16}$. The following was obtained:

$$\theta = \frac{\pi}{4}, \quad a = 0.1145, \quad \frac{h}{l} = 1.16 \sin\theta = 0.820,$$

$$\theta = \frac{\pi}{16}, \quad a = 0.7452, \quad \frac{h}{l} = 1.19 \sin\theta = 0.232.$$

Let us consider (from the qualitative point of view) one more example of the variation of the velocity hodograph. In Fig. 2 we have a dam with inclined slopes, the angle between which θ_0 is less than $\frac{\pi}{2}$, h_1 and h_2 are the depths of the up-stream and down-stream water, l — the length of water-tight foundation. If $\frac{h_1 - h_2}{l}$ is small, then on the velocity hodograph we have the point B corresponding to the turning point of the free surface. When $\frac{h_1 - h_2}{l}$ increases, B tends to C; then, instead of the incision CB the incision CB_1 appears which, at the filling of the dam, passes into the segment CB_2 whereby the part CB_2A disappears. If $\theta_0 = \frac{\pi}{2}$, then the points C and A of the hodograph coincide, the incision CB_1 becomes impossible and the turning point always exists, except, in the limiting case, when the point B coincides with the point C. If $\theta_0 > \frac{\pi}{2}$, then the free surface, on which there is a turning point, will always exist including the case of the full raise of water. The velocity hodograph will all the time have the incision AB along an arc of a circumference (the point C on the hodograph will be below the point A).

If $h_2 = 0$, i. e., if there is no down-stream water, then the point E of the hodograph will occupy the position E_1 and the upper part of the hodograph will disappear [3].

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PHYSICS

LOW FREQUENCY SCATTERING SPECTRA IN PARA-, META- AND ORTHO-DIIODBENZENES

By E. F. GROSS and A. V. KORSHUNOV

(Communicated by D. A. Rojdestvensky, Member of the Academy, 27. IV. 1939)

Gross and Vuks (1) have observed in crystals of organic substances a new type of scattering spectrum to which they gave the name of «low frequency scattering spectrum», on account of its lying in the region adjacent to the Rayleigh line. The above writers suggested an explanation of the origin of that spectrum. According to their interpretation, the low frequency scattering spectrum is due to intermolecular vibrations, to vibrations of the crystalline lattice of the substances studied. After the investigations made by Vuks (2) and those made by Gross and Komarov (3) there can hardly be any doubt as to the fact that the low frequency of Raman spectrum is due to intermolecular vibrations in the substance. The experiments made by Gross and Raskin have shown the existence of the low frequency scattering spectrum to be due to vibrations of the crystalline lattice.

So far little can be said as to the nature of the crystalline lattice vibrations that give rise to the low frequency spectrum. Most of the organic substances, not excepting those whose low frequency spectra have up to now been studied, are known to exhibit a crystalline lattice of the so-called molecular type. The forces acting between the atoms of an individual molecule are much greater than the intermolecular forces (the van-der-Waals' forces) combining the individual molecules into a lattice. It would therefore seem natural to imagine the individual molecules in the molecular lattice as being to some extent rigid, hard formations, capable as a whole of motion within the crystalline lattice. It may therefore be thought that, in addition to translational vibrations about the centres of gravity, the molecules in a molecular lattice can perform angular vibrations (librations) about the position of equilibrium.

We regard it as probable that these very vibrations of whole molecules, both translational and angular, give rise to the scattering spectrum of low frequencies.

It would be of interest to ascertain, by some method or other, which of the lines of the scattering spectrum of low frequencies are due to angular oscillations, and which are produced by translational ones. The first idea that suggests itself is to establish a connexion between the frequencies of the lines of the low frequency scattering spectrum, on the one hand, and the mass and the moments of inertia of the molecules, on the other. The frequency of translational vibrations in the crystalline lattice will be determined by the elastic forces acting within the lattice and the mass of the vibrating molecules $\left(\nu_T \approx \sqrt{\frac{f}{M}}\right)$. As to the frequency of the angular vibrations, it depends

on the elastic forces and on the moment of inertia of the molecules $\left(\nu_B \approx \sqrt{\frac{K}{I}}\right)$. To carry out such a comparison of frequencies is no easy matter, since the elastic forces which, along with the mass and the moment of inertia, determine the vibration frequencies, differ as to the case. Consequently, a comparison of the lines due to translational vibrations, on the one hand, with those due to angular oscillations, on the other, can only be carried out if the effect of the elastic forces can be eliminated. And this seems to be possible only in case spectra of such substances are compared whose molecules have the same structure but are composed of different isotopes.

In this connexion of great interest are the experiments of Bauer and Magat (4) who compared the Raman spectra of heavy and ordinary water. From a comparison of the Raman spectra of those two substances whose molecules have about the same mass, but different moments of inertia, Bauer and Magat infer the existence of translational and angular intermolecular vibrations of the water molecules. By assuming the existence of similar vibrations Bernal and Tamm (5) deem it possible to explain the differences in some physical properties of ordinary and heavy water.

We regret to have had as yet no opportunity of performing similar experiments with organic substances giving rise to the Raman spectrum of low frequencies.

In the light of the above we thought it of interest to approach the problem of the nature of vibrations taking place in a crystalline lattice by investigating the Raman spectrum of such substances whose molecules, while having the same mass, are different structures, and, consequently, show different moments of inertia. These conditions are satisfied, e. g., by the dihaloido-derivatives of benzene, in which the halogen atoms are in the para-, meta- or ortho-positions. In experimenting with such substances we are of course unable to eliminate the elastic forces operative in their crystals, so that our experiments lack the conclusiveness attainable in experiments with, say, heavy and ordinary water. We therefore regard them merely as an attempt to approach the solution of the problem concerning the nature of the vibrations taking place in the crystalline lattice of organic substances giving rise to the Raman spectrum of low frequencies.

In comparing the low frequency scattering spectra as attempted by the authors, one should endeavour to mitigate, as far as possible, if not to eliminate, the effect produced by the forces acting within the crystal upon the results of the comparison. This may be achieved to a certain extent by the choice of such objects of investigation whose crystalline lattices are most closely related to each other.

In selecting our object we decided in the first place for para- and meta-diiodbenzenes. The crystalline lattices of both these substances have been thoroughly investigated by means of X-rays by Hendricks and others (6). As shown by those investigations, both substances crystallize in the same crystallographic system and have the same number of molecules in the elementary cells, the dimensions of the latter being almost identical in either substance. Even the spacings between some of the corresponding atoms of neighbouring molecules retain in the para- and meta-positions nearly equal values. It should, however, be noted that the molecule of meta-diiodbenzene has a dipole moment, while that of para-diiodbenzene has none. An additional dipole interaction should therefore be anticipated to exist in the lattice of meta-diiodbenzene.

We also studied ortho-diiodbenzene which, in the light of the above considerations, offers the same interest as para- and meta-diiodbenzene (the

same mass of the molecule). Unfortunately, however, data available as to the structure of the crystalline lattice of ortho-diiodbenzene are less complete than those for para and meta. From the works by Hendricks, Maxwell, Mosley and Jefferson ([6]) it is only known that the elementary cell of ortho-diiodbenzene contains, similarly to para and meta, four molecules, while its dimensions are different.

Para-, meta- and ortho-diiodbenzenes offer great experimental advantages, owing to their crystallization points (melting point 130° C, 34° C and 23° C, respectively). These temperatures, being neither too high nor too low, facilitate to a considerable degree the growing of monocrystals.

The growing of monocrystals of para-, meta- and ortho-diiodbenzenes was carried out by a method previously described ([1]). The crystals thus grown proved of a good quality and quite suitable for obtaining scattering spectra of low frequencies. The spectrograph used had a dispersive power of 15 Å/mm in the region of 4046 Å. The ultra-violet spectrum of the arc was absorbed by a 10% water solution of $NaNO_2$. The spectrogramms were taken with crystals at room temperature.

All the three substances show a low frequency scattering spectrum of high intensity. The table shows side by side the low frequency Raman lines observed for the three substances.

Diiodbenzenes (frequency in. cm^{-1})		
Para	Meta	Ortho
15	—	—
25	24	23
—	—	46
—	79	74
—	—	89
—	101	100
115	—	—
—	—	127

As may be seen from the above table, the spectrum of ortho-diiodbenzene contains a greater number of lines than either meta- or para-diiodbenzenes. This is probably due to a greater asymmetry of the ortho-diiodbenzene molecule compared with those of meta-and para-diiodbenzenes. Some common frequencies are to be observed in the spectra of the diiodbenzenes. Thus, both meta and para have practically the same frequencies at about 75 cm^{-1} and 100 cm^{-1}. Most significant is, perhaps, the fact that para-, meta- and ortho-diiodbenzenes all display a Raman line at about 24 cm^{-1}, whose frequency, within experimental error, is the same for all the three substances.

Is this agreement of frequencies a merely fortuitous one? In ordinary Raman spectra of para-, meta- and ortho-compounds some Raman lines are known to coincide. This agreement of frequencies is evidently due to the constancy of the corresponding bonds between the atoms of an individual molecule, a constancy that persists in the transition from ortho- to meta- and para-positions. How is then the constancy of the frequencies (unless it is fortuitous) to be interpreted if the Raman spectrum is due, as in our case, to intermolecular vibrations, to vibrations of the crystalline lattice? It is doubtful that this agreement of frequencies should be due to vibrations between individual atoms of neighbouring molecules, which remain constant in all the three diiodbenzenes. In the molecular lattice the difference in magnitude between the intramolecular forces, on the one hand, and the intermolecular ones, on the other, is usually considerable.

It would seem to us more natural to look for an explanation in the fact that all the three diiodbenzenes have the same molecular mass. In other words, we should like to see in the constancy of frequencies a confirmation of our idea of the nature of the vibrations taking place within a molecular crystalline lattice which, as stated above, was taken as the starting point of our experiments. The non-coincidence of the other Raman lines of low frequencies in the spectra of diiodbenzenes should then be possibly put down to the angular vibrations of whole molecules. The difference in the moments of inertia of para-, meta- and ortho-molecules involves a difference in the frequencies of such Raman lines.

Further experiments which are now in progress are to show in how far the above interpretation of the results obtained is correct.

We are greatly indebted to Dr. D. V. Tischtschenko who kindly undertook the control over the preparation, at the Institute of Chemistry of the Leningrad State University, of the substances used in our experiments.

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PHYSIK

EINWIRKUNG DER TEMPERATUR AUF DAS SPEKTRUM DER ULTRAVIOLETTEN LUMINESZENZ VON NaCl-UND KCl-KRISTALLEN

Von M. N. PODASCHEWSKY und A. M. POLONSKY

(Vorgelegt von S. I. Wawilow, Mitglied der Akademie, d. 14.VI. 1939)

1. In ihrer vorigen Arbeit haben die Verfasser (1) die Spektralverteilung der ultravioletten Lumineszenz von NaCl- und KCl-Kristallen erforscht. Es wurde dabei festgestellt die Lage der Maxima der Lumineszenzstreifen und ihre Halbwertsbreite bei Zimmertemperatur.

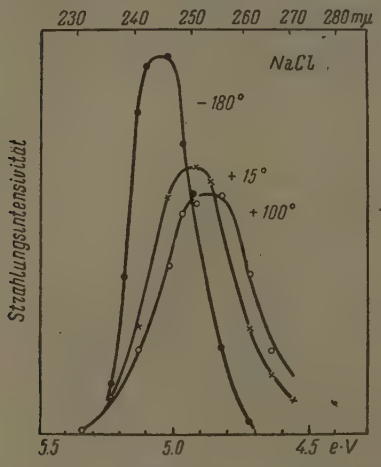

Fig. 1.

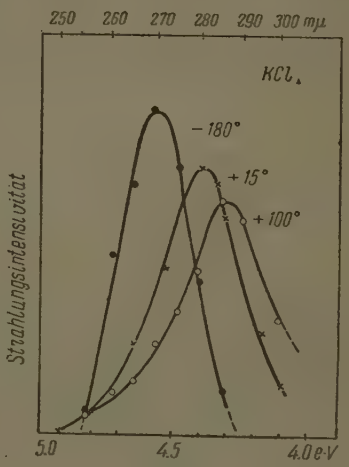

Fig. 2.

Bei Betrachtung der Energiezustände der Elektronen im Kristallgitter und bei Berechnung der Energieniveauschemas sind die Temperatureinflüsse zu beachten. Wie bekannt, hängen die optischen und photoelektrischen Eigenschaften der Alkalihalogenidkristalle, insbesondere die Lagen der Absorptionsspektra von *F*-Zentren, von der Temperatur ab (2).

Die vorliegende Arbeit bezweckt den Temperatureinfluss auf die Spektra der ultravioletten Lumineszenz von photochemisch verfärbten Halogenidsalze der Alkalimetalle zu erforschen.

Die angewandte Versuchsanordnung ist, im wesentlichen, der früher beschriebenen analog (1). Die beantragten Änderungen laufen auf folgendes hinaus: die zu untersuchenden Kristalle waren in einer Hochvakuumkammer mit einem metallischen Dewargefäss befestigt, welches eine beliebige Zeit die nötige Temperatur konstant erhalten liess. Der zu untersuchende Kristall

war von drei Seiten durch Halter aus Kupfer erfasst und befand sich in einem Abstand von 1.0—1.5 mm von der Auftrittsspalte eines doppelten Quarzmonochromators. Das Dewargefäss war mit einem dünnen Quarz- und Fluoritfensterchen zur photochemischen Verfärbung des im Gefäss befestigten Kristalls versehen. Die Intensität der Lumineszenz wurde mittels eines höchstempfindlichen Platinwasserstoff-Lichtzählrohrs registriert.

2. Es wurden die Spektra der ultravioletten Lumineszenz bei hoher Temperatur getemperter Steinsalz- und synthetischer KCl-Kristalle, insgesamt an 30 Exemplare, untersucht. Die Kristalle wurden mit dem Licht eines kondensierten Aluminium Funkens verfärbt, manche Kristalle wurden röntgenisiert. Die weiter angeführten Resultate wurden mit Berücksichtigung einer Korrektion auf Spektralempfindlichkeit des Lichtzählrohrs erhalten.

Die Messungsergebnisse bei Temperaturen von—180°, +15° und +100° C lauten wie folgt:

1. Eine Temperaturerhöhung ruft eine Erweiterung des Lumineszenzstreifens hervor.

Tabelle 1

	Temperatur in C°		— 180°	+ 15°	+ 100°
NaCl	Lage des Maximums	mμ	244	249	252
		eV	5.06	4.95	4.90
	Halbwertsbreite	eV	0.25	0.35	0.40
KCl	Lage des Maximums	mμ	270	280	286
		eV	4.56	4.41	4.31
	Halbwertsbreite	eV	0.30	0.35	0.40

2. Es wird dabei eine Verschiebung des Maximums zum langwelligen Teil des Spektrums hin beobachtet.

In Fig. 1 und 2 sind die für NaCl- und KCl-Kristalle erhaltenen Kurven dargestellt. Auf der Ordinate ist die Lumineszenzintensität in willkürlichen Einheiten notiert, auf der Abszisse die Energien in eV und die ihnen entsprechenden Wellenlängen in mμ. Die Kurven sind auf eine gleiche Fläche reduziert. Tabelle 1 enthält die von uns erhaltenen quantitativen Angaben.

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Odessa.

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ZITIERTE LITERATUR

[1] M. N. Podaschewsky u. A. M. Polonsky, C. R. Acad. Sci. URSS, XXI, 15 (1938). [2] E. Mollwo, ZS. f. Phys., 85, 56 (1933).

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CHEMISTRY

ANNUAL CHANGES IN THE HYDROCHEMICAL CONDITIONS IN THE YASHALTA LAKES

By V. I. NIKOLAEV and B. I. STEPANOV

(Communicated by N. S. Kurnakov, Member of the Academy, 11. VI. 1939)

In the western part of the Kalmuck A. S. S. R. southwest of the town of Elista and not far from Yashalta village is situated the Yashalta group of four lakes: Big Yashalta, Little Yashalta, Tsarik and Jama.

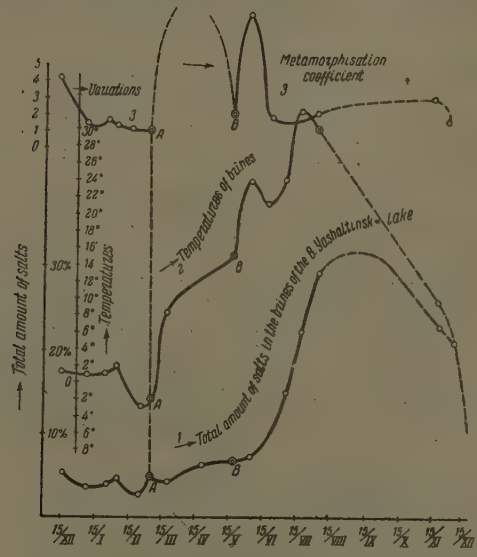

Fig. 1.

There is no doubt that the first three lakes mentioned which have a high coefficient of metamorphization can be utilized for the industrial production of Glauber's salt-sulphate.

The quantity of brine in the lakes amounts to 2—3 million cubic meters (roughly estimated) which makes it possible to extract about 450 000 tons of Glauber's salt (200 000 tons of sulphate) on their winter precipitation in basins. The lakes are very well fed by underground brines which are leaching the surrounding soil heavily stored with salts. This fact further

extends the period during which these lakes can be utilized as a source of magnesium and sodium sulphates.

As our aim is to trace the conditions of the brines in the various months of a year (1938) the following indices are of importance: the time when each sample was taken, the temperature of the brines and of the air, the total amount of salts in the brines and the metamorphization coefficient.

All these values are given in tables and recorded graphically (Figs. 1 and 2).

Brines of Big Yashalta Lake

	Date of sampling	Brine temperature °C	Air temperature, °C	Total of salts in brine	$K = \frac{Mg\ SO_4}{MgCl_2}$
1	15.XII.37	4	4	5.12	4.10
2	7.I.38	1	2	3.57	1.23
3	22.I.38	1	2	4.0	1.54
4	6.II.38	2	2	4.66	1.31
5	21.II.38	—3	—6	2.72	1.16
6	5.III.38	—2	—6	4.73	1.09
7	22.III.38	8	6	4.35	Instead of $MgCl_2$ the brine contains Na_2SO_4
8	21.IV.38	12	10	6.12	
9	20.V.38	15	13	6.68	1.79
10	5.VI.38	24	20	7.21	7.70
11	19.VI.38	21	19	10.00	1.44
12	5.VII.38	24	24	15.00	1.11
13	22.VII.38	32	32	22.10	1.19
14	6.VIII.38	30	27	29.10	1.62

Brines of Little Yashalta Lake

	Date of sampling	Brine temperature °C	Air temperature, °C	Total of salts in brine	$K = \frac{Mg\ SO_4}{Mg\ Cl_2}$
1	15.XII.37	4	4	0.71	5.0
2	22.I.38	2	2	4.96	0.83
3	6.II.38	3	2	3.80	1.93
4	21.II.38	—2	—6	5.65	0.77
5	5.III.38	—3	—5	3.48	1.45
6	21.IV.38	15	12	4.10	1.08
7	20.V.38	17	15	10.0	1.89
8	5.VI.38	26	19	7.70	2.10
9	19.VI.38	19	17	12.0	2.15
10	10.VII.38	29	28	23.0	2.39
11	23.VIII.38	27	28	27.5	1.9

A comparison of the upper curve (variation of the metamorphization coefficient) and the middle curve (temperature) with curve *I* characterizing the changes that take place in the composition of the brines during the year will show that:

1) At the beginning and at the end of the year the brines in Big Yashalta lake are diluted, unsaturated.

2) From the middle of March to the middle of May (section *AB* on all three curves) the coefficient of metamorphization becomes so high that ma-

Brines of Tsarik Lake

	Date of sampling	Brine temperature °C	Air temperature, °C	Total of salts in brine	$K = \frac{MgSO_4}{MgCl_2}$
1	14.XII.37	1	1	3.48	1.18
2	7.I.38	1	0	3.60	1.54
3	21.I.38	1	0	3.04	1.52
4	21.II.38	—2	0	5.02	0.97
5	8.III.38	2	3	2.70	2.04
6	23.III.38	4	10	1.03	2.83
7	21.IV.38	29	20	7.20	2.18
8	5.VI.38	27	21	4.48	1.52
8	19.VI.38	21	20	6.28	1.54
10	5.VII.38	26	26	12.0	1.65
11	21.VII.38	26	26	30.25	2.08
12	6.VIII.38	—	—	30.95	1.20*
13	22.VIII.38	19	19	30.5	1.10
14	25.IX.38	1	9	27.27	1.06

gnesium chloride disappears from the brines and the ratio $\frac{MgSO_4}{MgCl_2}$ is replaced by the ratio $\frac{Na_2SO_4}{MgSO_4}$. This can be explained by the inflow of spring waters leaching the surrounding soil which contains large amounts of sulphates.

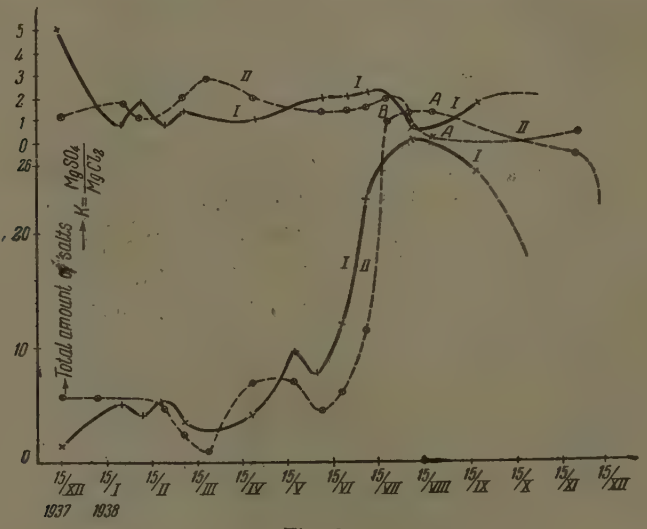

Fig. 2.

3) On about May 20 (point *B*) intense evaporation sets in, the temperature jumps from 15° C to 30° C and even higher. The coefficient of metamorphization settles after some fluctuations at about 1.4—1.5. At the end of July or in August the sodium chloride begins to precipitate. The total of salts in August 1938 amounted to 29.10%. Fig. 2 shows the annual changes in the composition of the brines of Little Yashalta lake and lake Tsarik.

* NaCl precipitates.

The figures show similar fluctuations in the composition of the brines, in temperature and in metamorphization coefficient; but the latter does not go as high as in the case of Big Yashalta lake. For lake Tsarik it amounts to 2.83. At the moment of NaCl precipitation (July 21, 1938), $K = \frac{MgSO_4}{MgCl_2}$ comes to 2.08 for this lake; for Little Yashalta it comes to about 2.4. We can regard the values for K at the moment of precipitation as the most stable and as sufficiently determining the physical chemical character of the lakes mentioned. As these values are comparable with the Karabogaz coefficient of metamorphization and as the maximum concentrations are reached only in July—August it becomes perfectly clear that only the summer brines of the lakes mentioned should be used for the production of mirabilite.

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CHEMISTRY

UTILIZATION OF LAKE BRINES FOR THE PRODUCTION OF MIRABILITE (SODIUM SULPHATE) AND MAGNESIUM COMPOUNDS

By V. I. NIKOLAEV, E. V. GRITSEVITCH and L. S. DYNKINA

(Communicated by N. S. Kurnakov, Member of the Academy, 11. VI. 1939)

The concentration curve for the total of salts of Karabogaz brines at the outset of NaCl precipitation has already been obtained at the Institute of General and Inorganie Chemistry and Institute of Halurgy.

Brines not saturated with sodium chloride are known to deposit pure crystals of Glauber's salt on cooling but no adequate plot is available of the dependence of the yield upon the metamorphization coefficient and the ratio $\frac{Cl'}{Mg}$ ... We have decided therefore to determine these relations experimentally on some of the brines from the various lakes of the Volga delta.

In Fig. 1 the beginning of NaCl precipitation is plotted against metamorphization coefficient. The crosses denote the composition of the unsaturated solutions used to determine the amount of Glauber's salt precipitated on freezing. The coefficients of metamorphization for the brines were: 0.38; 0.73; 0.96; 1.30 and 1.75. The solutions were cooled to —8° C, i. e., to a temperature which is sure to occur in the lakes of the Volga delta and in particular in the Kalmuck A. S. S. R.

Quantity of Glauber's Salt Precipitated

Sample No.	Ratio $\frac{Cl'\ (\text{weight}\ \%)}{Mg''\ (\text{weight}\ \%)}$ in the brines	Metamorphization coefficient	Total amount of salts in the initial brine (weight %)	Temperature at the beginning of crystallization, °C	Quantity of Glauber's salt precipitated per cubic meter of brine	Quantity of sulphate corresponding to Glauber's salt precipitated from one cubic meter of brine	Analyzed by
1	4.2	0.38	25.13	—6	44	19.5	E.V.G.
2	4.2	0.73	26.34	—1.8	95	42	L.S.D.
3	4.5	0.96	27.5	0.0	122	53	E.V.G.
4	4.3	1.30	27.35	3.5	160	70	E.V.G.
5	4.1	1.75	27.62	7.2	209	92	L.S.D.

In Fig. 2 the amounts of Glauber's salt precipitated are plotted against metamorphization coefficient and the temperatures at the beginning of precipitation.

With these plots we have a good clue to control the conditions under which the precipitation of Glauber's salt for its industrial production in basins takes place. Of the lakes situated in the Kalmuck A. S. S. R. the Yashalta group consisting of four big lakes is the first to be considered from the industrial point of view.

Three of the lakes (Big Yashalta, Little Yashalta and Tsarik) which have high coefficients of metamorphization—from 1.5 to 2—approach to the Karabogaz lake by the composition of their brines. From our diagrams and repeated laboratory experiments we may therefore expect that when especially constructed basins filled with brine during the summer (July and August), the concentration of brine in the lakes mentioned coming then very close to that corresponding to the beginning of common salt precipitation, are cooled

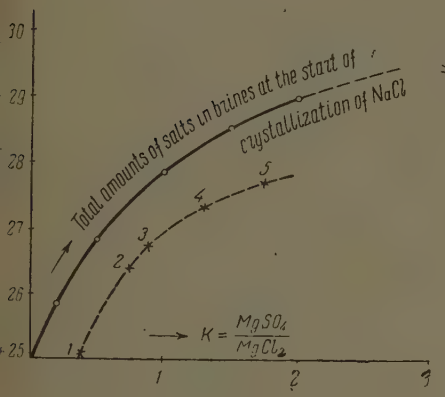

Fig. 1.

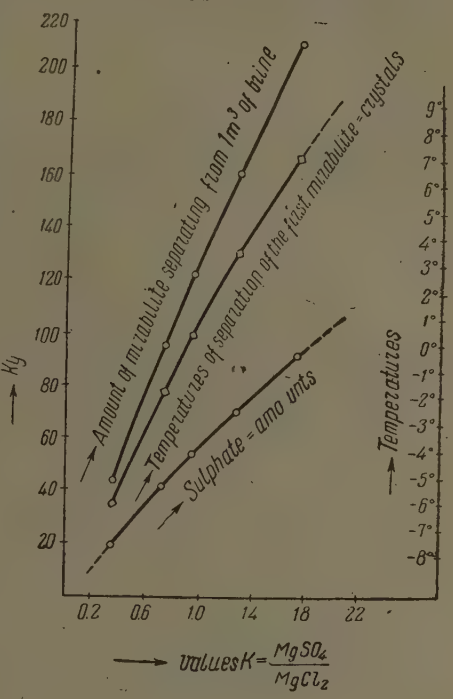

Fig. 2.

in winter to—8° C, we will get a precipitation of no less than 180 kg of Glauber's salt per cubic meter of brine. As atmospheric precipitation in the Yashalta lakes district amounts to 400 mm annually, it would be most rational to replace the drying of the Glauber's salt in the sun by the use of sodium metasilicate (or silicate «slump») which would require the building of a small plant near the basins and Yashalta village. After Glauber's salt has deposited, the brines may be evaporated farther to produce magnesium chloride which is greatly needed in the Kalmuck A.S.S.R.

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CHEMISTRY

KINETICS OF ADHESION OF MINERAL PARTICLES TO AIR BUBBLES IN FLOTATION SUSPENSIONS

On the Theory of the Flotation Process

By M. A. EIGELES

(Communicated by E. V. Britzke, Member of the Academy, 8. VI. 1939)

Among the methods of physico-chemical study suggested during the last two decades for establishing the relation between the state of the mineral surfaces and the flotability of the minerals, the most elaborately developed ones are those which connect flotability with the magnitude of the edge angle, formed by the contact of three phases ([1,2,3]).

There is no doubt as to the existence of a relationship between the magnitude of the edge angle and the flotability of the mineral. Nevertheless the problem of the least value of the edge angle necessary for the flotation of a mineral particle, and of the rôle of flotation reagents in the elementary flotation act needs further study. The unwettability of the mineral particle when the edge angle is greater than 90° is at present considered unnecessary for flotation. However, many research workers believe that a sufficiently large magnitude of the edge angle is necessary for flotation of minerals, and that the rôle of accumulators consists in attaining this ([2,3]).

The author made an experimental study of the adherence of mineral particles to an air bubble. In order to bring the method of research closer to the real conditions of the froth flotation process we decided not to study the adhesion of the bubble to a treated mineral surface as has been done in a number of works ([1,3,6]). In our work we studied the adhesion to an air bubble of mineral particles whose grade of coarseness is usual in flotation. These two phenomena, as is shown below, are brought about by the operation of different forces.

The force for the average fluorite particle of class 0.06—0.15 mm to be torn away equals 12×10^{-4} dynes*, while the hydrostatic vector of a spheric air bubble 5 mm in diameter (the adhesion of a 5 mm bubble was studied by Wark) equals 64 dynes, i. e., 50 000 times greater. The force of attraction necessary for the adherence of a 5 mm air bubble (contact along a circle 0.12 cm in radius) is 85 dynes/cm to one cm of adhesion perimeter, and for the adherence of the fluorite particle mentioned above the force equals 37×10^{-3} dynes/cm, i. e., 2300 times less than in the first case. Thus, the force of attraction which has been studied by a number of research workers is many times greater for the adhesion of an air bubble to the mineral than that necessary for the fixation of mineral particles of flotation grade on the bubble.

* The edges of the particle are taken as 1 : 1 : 0.5.

It is the kinetics of adhesion of mineral particles that was the object our study. The influence of flotation reagents on the time of adhesion a bubble to a polished mineral surface was first studied by I. Sven-Nilsson([6]). e takes the adhesion time of 5 sec. as characterizing the flotation abilities the mineral. This time is greater than the mean time that an air ıbble stays in the laboratory flotation machine, and is far from the real nditions of the flotation process. In studying the adhesion of an air ıbble to a large mineral surface Sven-Nilsson studied forces considerably eater than those necessary for the fixation of mineral particles on the rface of a bubble.

In order to study the kinetics of the adhesion of mineral particles to a bubble e author constructed an electrocontact apparatus which is a further deve- pment of the Taggart bubble apparatus ([1]) used by Wark and Sven-Nils- n ([3,8]). In passing over to the study of the adhesion of mineral particles we und that the time of contact between the particles and the bubble necessary r adhesion is very small; as a result of this it was necessary to make some anges in the construction of the apparatus.

The main part of the contact apparatus proper is the vertically moving ble which brings the cuvette with the test powder and the solution to the curately adjustable bubble holder. The contact time is regulated by means an interrupter which consists of an illuminating apparatus, a photoshutter, otoelement and amplifying apparatus. The shutter makes it possible to illu- nate the photoelement for from 0.01 to 1.0 and more seconds, and, by swit- ing on the electromagnet for a corresponding time, to bring the powder o contact with the bubble. The time of illumination of the photoelement given in the tables.

The study was made for pure minerals—fluorite, barite and calcite. We established that mineral particles of the size commonly used in flota- n adhere to air bubbles in pure water without reagents of any kind.

Clearing the mineral surfaces after several methods did not alter the nesion itself. Fluorite of size 0.15—0.20 mm was carefully washed and cined at a temperature of 300°—800°. Other weighed portions of it were ated with hydrochloric acid and washed many times. Then the fluorite s reduced to powder by grinding pure crystals under water. The water d was twice and thrice distilled. In all cases the mineral particles adhered the air bubble.

The contact time necessary for the mineral particles and the air bubble stick together depends very noticeably on the size of the particles. ble 1 shows the adhesion time of mineral particles in pure water in relation their size. It increases noticeably as the size of the particles increases.

The durability of adherence not great without an accu- lator. If shaken horizontal- a little, the particle moves ng the spheric surface of the ble under the action of the ck, and it takes a compara- ely small shock to tear away adhering mineral particle. e greatest adherence dura- ity was observed in fluorite. The adhering of mineral ticles to an air bubble in re water contradicts the

Table 1

Size of particles in mm	Adhesion time in sec.		
	Fluorite	Barite	Calcite
0.6—0.75	—	Does not adhere up to 1800	Does not adhere up to 1800
0.5 —0.75	1800	—	—
0.4 —0.6	300—600	—	1800
0.3 —0.4	60—120	—	20
0.25—0.3	5—10	—	15
0.15—0.2	0.5—1.0	60—120	—
0.06—0.15	0.04	30—60	30

conclusions of a number of research workers ([1,3]) who consider contact between an air bubble and a pure mineral surface to be impossible without reagents. We consider it impossible to explain the adhesion of particles through impurities on their surfaces. Adhesion should have some relation to the very small value of the attraction forces necessary to fix the particle to the bubble;

The following equation was proposed by Wark ([3]) and independently of him by Frumkin and Kabanov ([4]) for calculating the adhesion forces of an air bubble to a surface:

$$L = 2\pi a\sigma_{12} \sin\theta - \pi a^2\sigma_{12}\left(\frac{1}{R_1}+\frac{1}{R_2}\right), \qquad (1)$$

where a is the radius of the area of adhesion, σ_{12}—the surface tension at the interface liquid—gas, θ—the edge angle, R_1 and R_2—the curvature radii of the main sections of the bubble at the level of the adhesion surface. The conditions of fixation of particles at the interface air bubble—solution was examined afterwards by Volkova ([5]).

On the basis of equation (1) we can calculate the edge angle necessary to put the particles into equilibrium. Transforming equation (1) we got the following equation for the equilibrium of a particle adhering to an air bubble in a horizontal plane face:

$$\sin\theta = \frac{q}{\pi\sigma_{12}a} + \frac{a}{R_2} \qquad (2)$$

where q is the weight of the particle in water in dynes.

Table 2 gives the minimum values of the edge angle, calculated by equation (2). These values determine the equilibrium of cubic fluorite particles adhering in a horizontal face to an air bubble with R_2 equal to 0.1 cm. The adhesion area is taken as the circle inscribed in the face of the cubic particle.

Table 2

Edge of cubic particle in mm.	0.5	0.3	0.25	0.15	0.06	0.03	0.005
Weight of particle in water in dynes	$2.68\cdot10^{-1}$	$5.78\cdot10^{-2}$	$3.35\cdot10^{-2}$	$7.22\cdot10^{-3}$	$4.63\cdot10^{-4}$	$5.78\cdot10^{-5}$	$2.68\cdot10^{-7}$
Edge angle . . .	17°25′	9°40′	7°55′	4°35′	1°50′	0°55′	0°10′

The calculated values of the edge angle necessary for the mineral particles to adhere to the air bubble are very small. They are considerably smaller than those which a number of research workers consider as characterizing the flotation ability of the mineral ([1,3]). It is enough for the edge angle to be 5—10° that a mineral particle of flotation grade should fix itself on an air bubble in water. Such small edge angle values can be attained without an accumulator, and thus the adhesion of mineral particles to the bubble in pure water should be explained.

However, in spite of the fact that the mineral particle adhere to the air bubble, their flotation, regarded as a technological process, cannot be brought about without accumulators. A very important factor in the explanation of this phenomenon is the action of accumulators on the adhesion kinetics of particles, as studied by us.

In order that adhesion takes place in pure water it is necessary for the mineral particles to be in contact with the bubble for quite a length of time—seconds and tens of seconds (Table 1). The addition of accumulators which are used for the flotation of the minerals in question to the water greatly

reduces the adhesion time—to hundredths of a second. Besides the adherence durability increases. At ordinary flotation concentrations of the accumulator it is necessary to shake the bubble-holder strongly in order to throw off the adhering particle and often the latter can be removed only by breaking the bubble. Qualitatively it may be observed that the mineral particle is fixed more strongly, which is evidently analogous to the prenomenon established by P. A. Rehbinder (2) of the fixing of the wetting perimeter in the presence of an accumulator. Even when the particles are treated with an accumulator their size is still a factor in the adhesion time. In order to shorten the latter the large particles have to be treated with larger quantities of accumulator than the small ones. Table 3 gives experimental data on the influence of various concentrations of sodium oleate on the adhesion time of fluorite, barite and calcite particles.

Table 3

Expenditure of sodium oleate, g/t	Adhesion time in sec.			
	fluorite 0.3—0.4 mm	barite 0.15—0.2 mm	calcite 0.3—0.4 mm	calcite 0.15—0.2 mm
0.0	60.0	120.0	280.0	0.04
12.5	0.02	0.02	0.5	—
25.0	0.01	0.01	0.2	0.01
50.0	0.01	0.01	0.02	0.01
100.0	0.01	0.01	0.04	0.01
125.0	0.01	0.01	—	—
250.0	0.01	—	—	—
500.0	0.01	—	0.02	0.01
1000	0.01	—	0.20—0.50	0.01
2000	0.01	—	—	0.01
5000	0.01	—	—	0.20
10000	0.01—0.02	—	—	—
12500	0.01—0.02	—	—	—

The least illumination time for the photoelement taken in the experiments was 0.01 sec. The adhesion time of mineral particles to an air bubble in the presence of an accumulator, as established by us, is very small and, unlike the data given by Sven-Nilsson, can be related to the real conditions of the flotation process. When very great amounts of accumulator are expended, the adhesion time increases («overoiling»). The data obtained by us make it possible to define more accurately the rôle of the accumulator in the flotation act.

Accepting, in accordance with Frumkin's data (4), that after an air bubble has adhered to a solid body, the latter stays covered with an adsorptive layer of water, whose thickness is not greater than several molecules, we can consider the rupture of the unstable intermediate layers between the film of molecular thickness and the approaching air bubble to be the first stage of adhesion. The realization of the elementary flotation act when a mineral particle comes into contact with an air bubble under the real conditions of turbulent motion in the flotation machine depends upon two conditions: 1) on sufficient values of the forces of surface tension; 2) on the possibility for the particles to come into sufficiently close contact with the bubble by rupture of the intermediate liquid layer during the very short intervals of contact which are likely to occur in the turbulently moving suspension. The first condition determines the possibility of fixing the particle on the interface bubble—solution and is connected with the magnitude of the edge angle. The second condition determines the possibility of transforming the physical phenomenon of adhesion

into an element of the technological process of flotation, and is connected with kinetic rupture of the intermediate liquid layer between the particle and the bubble.

As our experimental data show, the first condition is realized more easily and is attained before the second for fluorite, barite and calcite. Small particles of fluorite, barite and calcite can be made to adhere to the bubble without accumulator. We have grounds to assume that many other minerals behave in the same manner. The reason why flotation of small particles does not take place without an accumulator is that the time of rupture of the intermediate liquid layer without an accumulator is too great. Adhesion takes place so slowly, that it cannot be realized under the conditions of the flotation machine.

The function of flotation accumulators is not only to increase the attraction between the particle and the bubble, but also to secure the necessary adhesion kinetics. It must be assumed that the latter is the most important part of their action in flotation.

Up till now the main attention in researches was paid to the influence of accumulators on the value of the edge angle. Adhesion kinetics was studied experimentally only in the work of Sven-Nilsson who was dealing, as we have noted, with the adhesion of a bubble to a large surface. The method accepted by us for studying the adhesion of mineral particles makes it possible to establish such a state of both boundary layers (particle—solution and bubble —solution) simultaneously, which secures rupture of the liquid layer between the particle and the bubble in a time suitable for flotation and the appearance of forces sufficiently great to fix the particles. The study of the final equilibrium values of the edge angle which permit to judge only of the limit adhesion force and is very far removed from the conditions of the unequilibrous flotation process, has been substituted for an examination of the kinetics of the fixation of the particle in the method accepted by us.

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CHEMISTRY

HYDROGENATION OF HEPTENE-1 AND *n*-HEPTANE UNDER HYDROGEN PRESSURE

By A. F. NIKOLAEVA and P. V. PUCHKOV

(Communicated by S. S. Nametkin, Member of the Academy, 16. V. 1939)

It has been demonstrated in a previous paper (1) that hexene-1 is easily hydrogenated at a temperature of 400°, in the presence of molybdenum disulphide, under a high pressure of hydrogen, and that next to *n*-hexane considerable amounts of isohexanes are thereby formed. *n*-hexane is also isomerized under these conditions with a considerable yield of isohexanes.

The present investigation was carried out in order to study similar transformations in the case of heptene-1 and *n*-heptane. Data available in the literature point to the possibility of the isomerization of *n*-heptane under conditions very near to those chosen by us (2).

n-heptane was obtained through the dehydration (3) of *n*-heptyl alcohol from Kahlbaum and the subsequent hydrogenation of heptene-1 by the method of Skita at room temperature. *n*-heptane had the following properties: b. p. 96 — 98°/745 mm; $n_D^{20} = 1.3880$; $d_4^{20} = 0.6844$; aniline point 70.0*. 10 cm³ of this preparation were treated in four sealed tubes with 52 cm³ of nitric acid (sp. gr. 1.075) at 120°, by the method of Konovalov. The nitroproducts obtained were distilled at 190—198° and showed a refractive index $n_d^{22} = 1.4240$ (2-nitroheptane obtained from *n*-heptane by M. I. Konovalov had $n_D^{22} = 1.4242$). When heated on a water bath with a solution of potassium hydroxide 98% of this nitroproduct went into solution.

The hydrogenation of *n*-heptane (experiment No. 213) was carried out at 400°. Into a 1 l autoclave fitted with a stirrer were placed 40.6 g of heptane and 4.0 g of molybdenum disulphide. The initial pressure of hydrogen was 140 atm. The heating at 400° lasted 2 hours. The pressure at this temperature did not decrease. After the cooling of the autoclave the pressure was 138 atm. 34.8 g of a condensate were collected, which had a refractive index $n_D^{20} = 1.3872$ and a iodine value 0; 33 g of the condensate were distilled with an Arbusov column (of a somewhat reduced size) and two fractions were collected:

Fraction I: 78—95.5°; 11.0 g; $n_D^{20} = 1.3860$; $d_4^{20} = 0.6798$; an. p. 70.6°.

Fraction II: 95.5—98.2°; 17.3 g; $n_D^{20} = 1.3880$; $d_4^{20} = 0.6845$; an. p. 70.6°.

The end point of the condensate was 98.2°. The residue that condensed in the flask and in the column had $n_D^{20} = 1.4038$.

From the distillation data it may be seen that a considerable portion of the condensate distilled off below the boiling point of heptane, i. e., below

* The melting point of aniline was—65° C.

95.5°. The physical constants of this fraction were somewhat lower, corresponding to paraffinic hydrocarbons with branched chains.

Hence in this case, as well as in the case of *n*-hexane, a considerable isomerization of *n*-heptane into isoheptanes has taken place.

In order to prove that the fraction I, boiling from 78 to 95.5° actually contained isoheptanes with a tertiary carbon atom, this fraction was treated with nitric acid (sp. gr. 1.075) by the method of Konovalov. 13 cm³ of this fraction (in 4 tubes) and 16 cm³ of nitric acid were used. Heating at 120° lasted 24 hours. The nitro-compounds obtained (1.5 cm³) passed over at 188—200°. After the distillation they had $n_D^{20} = 1.4262$; $n_D^{22} = 1.4253$.

When 1.05 cm³ of distilled nitro-compounds were treated with a solution of potassium hydroxide and heated on a water bath (according to Konovalov), only 0.62 cm³ went into solution. The volume of the undissolved nitro-compounds (0.43 cm³)did not change when heated with a new portion of a potassium hydroxide solution.

The undissolved tertiary nitro-compounds had a refractive index $n_D^{20}=1.4276$. When reduced with tin and hydrochloric acid they dissolved completely. By treating this solution with an alkali a small amount of an oil with a biting ammonium smell was isolated. These data proved that *n*-heptane under conditions of destructive hydrogenation had undergone considerable isomerization with the formation of isoheptanes. Heptene-1 was obtained by the method described above and had the following properties: b. p. 94—98°; $n_D^{20}=1.4051$; $d_4^{20}=0.7029$.

The hydrogenation (experiment No. 214) was carried out as follows: 3.7 g of molybdenum disulphide were placed in a 1 l autoclave fitted with a stirrer and the pressure of hydrogen was raised to 90 atm. The autoclave was heated to 400° and, without stopping the stirrer, at a pressure of 250 atm., 37.5 g of heptene-1 were introduced in a lapse of 1 minute. At first the pressure in the autoclave rose from 210 to 243 atm. and then it began to fall. After 20 minutes the pressure became stable and in another 20 minutes the experiment was brought to an end. The condensate (31.6 g) had $n_D^{20}=1.3889$ and an iodine value 0.7. Hence all the heptene-1 was hydrogenated.

29.7 g of the condensate were distilled with an Arbusov column (of a somewhat reduced size) and two fractions were collected:

Fraction I: b. p. 80—94°; 5.6 g; $n_D^{20}=1.3848$; $d_4^{20}=0.6790$; an. p. 71.4°.

Fraction II: b. p. 94—98°; 19.9 g; $n_D^{20}=1.3880$; $d_4^{20}=0.6893$; an. p. 71°.

The end point of the condensate was 98°; after that the temperature began to drop. The residue that condensed had $n_D^{20}=1.4119$.

As it can be seen from these data, the hydrogenation of the condensate was not accompanied by any marked polymerization. From the boiling point of the condensate it may be seen that the formation of liquid products having a smaller molecular weight had not taken place either. This was confirmed by the cryoscopic determination of the molecular weight of fraction I. It was found to be 101.

The constants of fraction I, which were very near to those of the corresponding fraction obtained in experiment 213 (with *n*-heptane) showed that in this case too the formation of isoheptanes had been taking place.

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GEOLOGY

ON THE TWOFOLD GLACIATION OF THE WEST SIBERIAN LOWLAND

By M. M. FRADKIN

(Communicated by W. A. Obruchev, Member of the Academy, 5. VI. 1939)

The Quaternary glaciation of the West-Siberian lowland has of late strongly attracted the interest of geologists, geomorphologists, geographers and other scientific workers, the subject of their investigation being in its historical development connected with the geological past of the country. The rather abundant literature dealing with this question may be divided into two categories:

1. Very few works containing rough descriptions of several sections of the Quaternary and material on the history of glaciation, mainly of the banks along the middle and lower course of the rivers Ob and Irtysh.

2. Far more numerous compilatory works treating under various aspects the material published in works of the first type.

In most of these works solitary and sometimes poorly convincing data obtained at some southern point on the margin of glacial deposits are by means of imposing extrapolations extended to the whole expanse of the northern part of the West-Siberian plain. And sometimes such data are used as the basis for various theories as to the nature of the West-Siberian glaciation.

It is just in this way that, on the basis of a few investigations of terminal moraines of maximum glaciation and of the locality lying south, it was stated that the West Siberian lowland had undergone but one glacial period ([2],[5]). It is, however, quite obvious that deposits of the minor, secondary glaciation should be looked for much farther northward and not in the Ob valley where they might have been effaced, but rather over the interriverine areas, north of the latitude of Surgut. Yet we dispose almost of no data concerning the geological structure of this northern part of the West-Siberian plain, while the fragmentary informations available are neglected since they do not fit within the theoretical speculation referred to above.

Such was the case with the terminal morainic formations on the Ob river near Berezovo, and those met by B. N. Gorodkov ([3]) on the watershed between the rivers Agan and Pur.

In 1936 and 1937 the author of this article, travelling in boats and on foot, made a geological survey along the itinerary Surgut—north to the gulf of the Ob, along the river Torm-Yaun, interriverine area and Nadim river. The materials obtained point to the existence in the northern part of the West-Siberian lowland of two belts of terminal moraines and of two glacial periods in the Western-Siberia. Terminal moraines of one generally accepted maximum glaciation have been found long ago ([1]) near the village Samarovo at the mouth of Irtysh, and near Surgut, on the rivers B. Yugan and Vakh ([4],[7]).

The terminal moraine of the second glaciation has been found by us at the uppermost part of the Nadim basin, and it was probably its eastward extension which B. N. Gorodkov had seen on the watershed Agan—Pur, while in the west it may, possibly, crop out near Berezovo. The following main data are testifying to the terminal morainic nature of the upper part of the Nadim basin:

1. The locality of the Upper Nadim and its affluents presents a miniature highland. The relief is characterized by hills of ellipsoid form, attaining 30 to 40 m in height and stretching mainly north-westwards. Sometimes the edges of the hills meet forming a kind of round depression where small rivers are transformed into lakes. South of the ridge of hills there is an abrupt change in the relief which at once becomes smooth and sloping. Approximately at the same latitude B. N. Gorodkov ([3]) came across the terminal moraine on the watershed between Agan and Pur, describing it as follows: «Toward evening we saw a chain of hills up to 20—40 m high rise in front of us; the locality beyond was steeply going down. These high sandy hills with abundant pebbles and small boulders stretch approximately from the west to the east; surely these are terminal moraines of the recent glaciation».

2. The above described ridge of hills made up of boulder clay soils differs essentially in its lithological character from the whole territory lying to the South [the Surgut district, after J. S. Edelstein's ([7]) nomenclature, Trans-Obian area] and covered with fluvio-glacial blown sands which only occasionally, in the topmost portion of the bed, contain boulders and pebbles. The Nadim moraine is characterized, besides, by the abundance of boulders and pebbles of translucent, sometimes milky white quartz, of arkose sandstone, quartzites, porphyrites, sandstones, chlorite-quartz and carbonaceous shales, grandiorites and other rocks. Thus, according to the petrographic composition of the boulders, the Nadim moraine differs from that of Samarovo ([1]), where boulders of gneisses, diorite, syenite, serpentine, sandstones predominate and that of Yugan and Vakh ([4—7]), with the prevalence of «trapps», limestones, gaizes, quartzites, shales, sandstones.

3. The boulder clays of the Nadim moraine are transgressively overlying the fluvio-glacial sands of the Surgut district.

Summing up all the above said, viz., the sharp expression of the Nadim moraine in the relief, its lithological distinction from the more southern district and moraines of the first maximum glaciation, the high stratigraphic position of the moraine which is lying on fluvio-glacial sands of the first glaciation, the Nadim moraine should be regarded as terminal of the second glaciation of the West-Siberian lowland. Hence it follows that the northern part of Western Siberia had passed through two glacial periods during the Quaternary. The first was the maximum glaciation, extending to 60° N. lat.([6]); the ice of the second glaciation should have reached to the watershed between the rivers Torm-Yaun—Nadim—Agan—Pur, i. e., up to 63—64° N. lat.

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MINERALOGY

HIBSCHITE IN GEORGIA

By D. S. BELIANKIN, Corresponding Member of the Academy, and
V. P. PETROV

A quite original mineral by the name of hibschite from the Upper Turon contact marls, which form inclusions in the phonolite of Marienberg near Aussig in Czechoslovakia, was described, as we know, by F. Cornu (1905, 1906, 1907). According to Cornu, it is close if not identical to lavsonite as regards its chemical composition which is that of an aqueous alumosilicate of calcium with the following approximate formula: $H_4CaAl_2Si_2O_{10}$. However, it crystallizes not in the rhombic system as lavsonite, but in the cubic system in the form of little colourless octahedric edges which grow around tiny microscopic rhombic dodecahedrons of garnet, of yellow titanic melanite.

The most important constants of hibschite as given by Cornu are as follows: specific weight $D=3.05$, light refraction $N=1.67$, hardness by the Moos scale $H=6$. The mineral decomposes easily under the action of acids and alkalis. In pulverized form it gives an acid reaction on wet litmus paper, and after being calcined it gives an alkaline reaction.

In the Marienberg layers all the other large-crystalled minerals of contact marl, viz: calcite, apophyllite and natrolite, are pierced with tiny pieces of hibschite-garnet.

A preliminary report on hibschite was made at the conference of the Vienna Mineralogical Society April 3, 1905, and a more detailed publication on it appeared in the Tsch. Min.-Petr. Mitt. in 1906. In this publication another hibschite layer is reported—this time from the xenolite of contact limestone in the basalt at Oben (Ardennes) in Southern France. It grows around melanite just as Czech mineral. The rest of its paragenesis is: wollastonite, green pyroxene and the zeolites: natrolite and thomsonite. As a matter of fact, the French hibschite was described as early as 1893 by Lacroix, by whom it was mistaken for colourless garnet, so that only Cornu discovered its true hibschite nature.

In 1907 Cornu described the fundamental contacts between the Upper Turon marls and the Jungferstein phonolites in the vicinity of Neschwitz in Czechoslovakia, and here also hibschite with the same melanite nuclei was found together with apophyllite in the zone of greatest marl metamorphization immediately adjoining phonolite.

In 1909 on the basis of the fact that hibschite is easily decomposed by acids and gives an acid reaction, W. I. Vernadsky came to the conclusion

that its constitutional formula is probably: $H_2Al_2Si_2O_8\begin{matrix}H_2O\\CaO\end{matrix}$ which differs from the formula of lavsonite: $CaAl_2Si_2O_8 \cdot 2H_2O$.

These data exhaust all the first-hand literature on hibschite. In textbooks and handbooks it is reported as a rare, or very rare mineral.

At present we can somewhat supplement the list of hibschite beds by including the new Soviet bed, discovered by us in the vicinity of the village Nikortzminda in Western Georgia (Racha). There it is associated with the contact between chalk marls and teshenites. According to our observations made during a short visit to Nikortzminda in 1936, the teshenites of this place form a small massif, which outcrops in some places from underneath the deposits of the Middle and Upper Albian (Renngarten) which cover it. The contact marls, best denuded in the small quarry on the north-eastern outskirts of the massif, immediately near the village, are not altogether homogeneous; they are characterized by intermittent layers of dark greenish-brown, peanut, light pink and pure white colours. The thickness of some of the layers varies within the approximate limits of from 3—4 to 15—20 cm.

Microscopic examination of the contact rocks collected by us showed that they are composed mostly of fine-grained wollastonite which changes characteristically into fine-fibred xonotlite. The predominant companions of wollastonite are: 1) thomsonite in the more large-grained deposits and 2) poikilitic hibschite with tiny characteristic yellow-green garnet nuclei just as in France and in Czechoslovakia. This hibschite pierces equally through wollastonite and thomsonite. Occasionally it displaces those minerals from the rocks almost entirely.

In the green varieties of the rock wollastonite is attended by a green monoclinic pyroxene which ranks with hedenbergite in its high refringent power. In the varieties which are rich in calcite we find apophyllite instead of wollastonite and both calcite and apophyllite are overgrown with small particles of the same hibschite with garnet in its heart (Fig. 1).

The optic constants determined by us for silicates mentioned here are given in Table 1.

Table 1

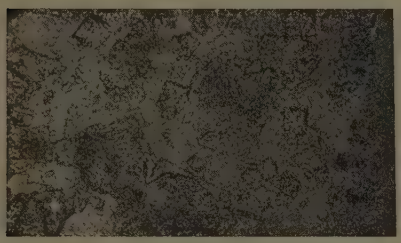
Wollastonite	$N' = 1.624 \pm 0.003$, $N'_p = 1.609 \pm 0.003$ $2V = -39°.5$; extinction angle in the section $\perp N_m$: $N_g - 100 = 33°$, $N_p - 001 = 35°$; angle between cleavages $100 - 101 = 87°$.
Xonotlite	$N'_g = 1.592 \pm 0.003$, $N'_p = 1.576 \pm 0.002$
Thomsonite	$N'_g = 1.530 \pm 0.003$, $N'_p = 1.518 \pm 0.003$
Green pyroxene	$N'_g > 1.730 > N'_p$
Hibschite	$N_{Na} = 1.681 \pm 0.003$. In monochromatic light: $\lambda = 500\,m\mu$. $N = 1.695$ $\lambda = 530\,m\mu$. $N = 1.682$ $\lambda = 615\,m\mu$. $N = 1.679$ $D = 3.05 \pm 0.03$
Garnet	$N = 1.815 \pm 0.003$ in the central predominating part of the grain, and $N = 1.808 \pm 0.003$ in the outer edges. $D = 3.68 \pm 0.03$.

For number of minerals the constants here referred to differ somewhat from those given in literature. Thus, the light refraction of our wollastonite is noticeably less than that of wollastonite in the handbook of Wülfing-Mügghe-Rosenbusch, 1926—27 (N_g from 1.632 to 1.634, N_p from 1.617 to 1.621). The birefringence of the xonotlite from Nikortzminda is somewhat higher than normal: 0.016 instead of Larsen's 0.10 (1928) and Flint, Murdie

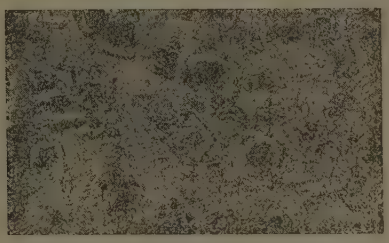
and Wells' 0.001 (1938). The refractive power of hibschite is one hundredth unit higher than Cornu gives (N=1.67).

Of all these data we consider the most curious the refringency of Nikortzminda wollastonite which is lower than the norm. Judging by its paragenesis with aqueous hibschite, which precedes it in its time of deposition in the contact rock, the most probable reason for this phenomenon must be the solid solution of water in wollastonite. When determined by the additive formula which shows the relation between composition and light refraction, the concentration of this solution turns out to be 1.3 per cent H_2O by volume and 0.5 per cent by weight.

Now passing to our hibschite, we deeply regret that the material we have at hand has not yet permitted us to extract the mineral from the rock in its pure form and in sufficient quantity to analyze it chemically



A



B

Fig. 1.

in order to check the chemical formula given by Cornu. On the other hand, in order to regard this formula somewhat critically, we obtained some data as a result of additional observation of hibschite from Marienberg in a sample taken by us from the Museum of Mineralogy of the Academy of Sciences.

This sample is a small piece of xenolite in phonolite—of recrystallized marl which consists of calcite, apophyllite and natrolite, overgrown with poikilitic hibschite which has nucleic garnet inclusions,—everything just as described by Cornu. The hibschite constants according to Cornu's data were given by us above, but Cornu did not give the garnet constants, and thus we are the first to determine them: $N = 1.815 \pm 0.003$ in the centre of the crystal and N=1.808 at the edges which in this case predominate over the centre instead of being predominated by it, as we saw in the garnet of Nikortzminda hibschite. D=3.61±0.03.

As we know, Marienberg garnet was chemically analyzed by Cornu by subtracting the figures obtained from the figures of a total analysis of hibschite+garnet; the chemism of the hibschite itself was also determined.

Both analyses and the chemical composition of hibschite calculated from them are given in Table 2.

Table 2

	Total	Garnet	Hibschite	$H_4CaAl_2Si_2O_{10}$
SiO_2	37.70	32.15	37.12	38.09
TiO_2		6.08	—	—
Al_2O_3	22.38	6.65	32.82	32.69
Fe_2O_3	8.46	20.99	—	—
MnO	traces	traces	—	—
MgO	1.86	0.68	2.64	—
CaO	21.31	32.45	13.72	17.17
H_2O	8.59	0.95	13.70	11.45
	100.30	99.95		

Are these analyses faultless and are they in accord with the constants of both minerals?

As to hibschite we could only question the existence of such an agreement (N is too high?), but with regard to garnet we recalculated its chemism for its elementary components and hence deduced by means of the additive formula its theoretical constants according to its chemism. The results are given in Table 3, and they show that the theoretical constants are considerably higher than the real ones.

Table 3

	Mol. p. c.	Vol. p. c.	Sp. gr.	$\frac{V \times D}{100}$	N	$\frac{V \times N}{100}$
Grossular	30.15	29.09	3.53	1.027	1.735	0.5047
Melanite	58.25	59.79	3.75	2.239	1.895	1.313
Ti-melanite	8.69	8.67	4.30	0.373	2.357	0.2043
Pyrop	2.91	2.54	3.5	0.089	1.705	0.0433
				3.728		1.8836
(Residue in weight percent TiO_2 1.99 p. c., CaO 0.22 p. c.)				(3.61)		(1.808)

Thus, it is evident that there is something wrong with chemical analyses and particularly with that of TiO_2 (which, by the way, was not even shown in the total analysis).

We hope that in the near future we shall be able to visit Nikortzminda again and gather enough material to study chemically not only garnet and hibschite, but also wollastonite, which we expect to find in «aqueous» condition.

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* According to Makovsky (1939) $3CaO.\ Fe_2O_3.\ 3TiO_2$.

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MINERALOGY

DECOMPOSITION OF CASSITERITE BY FUSION WITH BORAX AND SOME DETAILS OF ITS COMPLETE CHEMICAL ANALYSIS

By I. D. BORNEMAN-STARINKEVITCH

(Communicated by V. G. Khlopin, Member of the Academy, 5. VI. 1939)

While searching for new methods of decomposing cassiterite I came upon the idea of making use of the property of tinstone of crystallizing out of fused borax, which was already applied by Wunder (1) in 1870 in the production of artificial cassiterite.

All the parts are fused together in a short time during which the fused mixture is stirred. Further complete analysis is somewhat complicated by the presence of boron which is, however, removed without any great difficulty by evaporating with sulphuric and hydrofloric acids. The fused mixture with borax dissolves very quickly in this mixture; if it is present in small pieces the reaction is even violent and the dish should be covered with a glass in order to avoid loss.

Then evaporation goes on calmly until a voluminous precipitate of borofluoric compounds appears which dissolves only when heated more strongly, liberating SO_3 gas and decomposing sulphuric acid according to the equation:

$$NaBF_4+H_2SO_4=BF_3+HF+NaHSO_4.$$

As a result of this fused sodium pyrosulphate remains, containing all the components of cassiterite. If treated with tartaric acid the whole mixture dissolves.

Further extraction of tin in the form of the sulphide is not rational, as of a part which strongly prevails over all the rest, but in this respect we have in view the possibility of selecting the conditions of tartarate hydrolysis in such a way that the earthy acids should precipitate, leaving the tin in solution. This should form the object of a special study.

The method of fusing with borax is quite appliable to determining tin by iodometric titration, where it is unnecessary to remove boron from the solution. The analyses of cassiterites from two layers of the Kalbin range are described below. The samples were given to me by J. D. Gottman.

A spectroscopic analysis (S. A. Borovick) showed the presence of the following elements besides tin: Si, Ti, Zr, Nb, Ta, Fe, Mn, therefore the method used is limited only to these components.

1. Determination of Tin. 3—4 g of fused borax (it is best to fuse the borax in small quantities in a platinum dish covered with a platinum plate) are fused in a platinum crucible and after cooling a weighed portion of 0.2—0.3 g cassiterite is added. The crucible is covered and

Results of Cassiterite Analyses

	I Upper Bai-Murzinsky layer			II Urunkhai	
Sp. gr.	6.932	Ta_2O_5	1.22	6.950	1.06
SnO_2	96.97 per cent	Nb_2O_5	0.74	97.64 p.c.	0.81
SiO_2	0.06	Fe_2O_3	0.55	0.10	0.35
TiO_2	0.23	MnO	0.03	traces	0.05
ZrO_2	0.15	Others	0.07	traces	0.15
			100.02 per cent		100.14 per cent

heated in an electric crucible furnace at 900° for 15—20 minutes. Then a platinum spattle is put into the crucible and then the pulverized cassiterite which has settled at the bottom is carefully stirred with the flux by means of tongs with platinum tips, until a completely homogeneous mass is obtained. The crucible is closed with a cover which is so bent that the crucible be tightly closed in spite of fact that there is a spattle in it. The furnace is covered and left at 900° for about $^1/_2$ hour, after which the contents of the crucible are carefully mixed with the spattle every 20—30 minutes; in doing this it is advantageous to take the crucible out of the furnace, put it into a tightly fitting triangle and then mix; then the particles which stuck to the bottom of the crucible are removed easily due to the viscosity and ductility of the cooled borax.

After 1½—2 hours the fusing is over. A pale rose colour in the fused mixture after being cooled shows that there are undecomposed particles of the mineral present which are invisible to the eye, and fusion should be continued.

When the crucible is taken out of the furnace the fused mixture is spread over the walls of the crucible with the spattle to make its further dissolution easier. While cooling the crucible should be covered to obviate loss which might happen from cracking of the glass-like fused mixture. The cooled crucible is placed into a beaker together with the spattle, water is poured over it, 5—10 ml H_2SO_4 and 50 ml HCl are added, then it is heated until the fused mixture is dissolved and transferred into a conic flask for reduction with aluminium and consequent iodometric titration (²).

If there are particles of undecomposed mineral at the bottom of the beaker, they should be gathered on a small filter and well washed with water, and then the filtrate should be dried with care, incinerated in a platinum crucible and fused with ½ g borax, for which not more than ½ hour is necessary. The fused mixture should be added to the main solution.

Titration is accomplished in a microburette of 5 ml capacity whose end has first been pulled out into a capillary tube so that each drop should be 0.005—0.01 ml. Then if the weighed portion of cassiterite is 0.3 g, each drop will correspond to 0.01—0.02 per cent SnO_2, and if the weighed portion is 0.2 g, each drop will correspond to 0.02—0.04 per cent SnO_2.

2. Determination of Si, Ti, Zr, Nb, Ta, Fe, Mn. The weighed portion is decomposed by reduction with hydrogen (²,³).

After being cooled in a current of hydrogen the weighed portion is transferred into a quartz dish and treated with concentrated hydrochloric acid; the boat is boiled separately in a test tube with concentrated hydrochloric acid and the solution is added to the main one; the dish is covered with a glass and gently heated; after the reaction is over the glass is taken off and the solution is evaporated in a water bath until dry. Hydrochloric acid is again added and then a few drops of bromine (4, 5); the dish, covered with a glass, is heated gently at first and then evaporated in a water bath

until dry. Evaporation is repeated 3—4 times, after adding hydrochloric acid and bromine.

Then according to the methods accepted by J. N. Knipovitch in his work quoted below (4) and by the Institute of Mineral Raw Materials the part dissolved in hydrochloric acid and the undissolved residue are treated separately. Niobium, titanium and zirconium are thus distributed in the same manner in both cases, and therefore it is much easier to continue further treatment in the following manner.

5—10 ml sulphuric acid is poured over the dry residue and then the latter is heated until no more or very little SO_3 vapours come off. The residue is treated with water and boiled; as a result of hydrolysis Nb, Ta, Ti and Zr and small quantities of unvolatilized tin precipitate out. After the precipitate has settled it is filtered and washed with water; the filtrate is precipitated with ammonia; iron and small quantites of Ti and Zr precipitate. The precipitate is washed 2—3 times with cold water, dissolved in hydrochloric acid and precipitated with either ammonia again in the presence of methyl red as indicator or pyridine in order to remove manganese completely. Both filtrates are poured together and evaporated; sulphuric acid is added, and then they are evaporated in a quartz dish to SO_3 vapours, adding nitric acid to free from organic matter if necessary. The solution is evaporated to small volume and diluted with water; nitric acid, silver nitrate and ammonium persulphate are added, and manganese is determined calorimetrically (see Tredvelle, II, book I, page 97).

The first precipitate obtained by hydrolysis is calcined, weighed and fused with potassium pyrosulphate. The fused mixture is treated in the crucible with tartaric acid, which is added approximately in the same quantity as the pyrosulphate taken for fusion; the solution is transferred into a beaker, heated and the precipitated silicic acid is filtered off. The weight of SiO_2 is checked by evaporating with hydrofluoric and sulphuric acids. Hydrogen sulphide is passed through the filtrate from SiO_2, at first while heating and then in the cold, whereupon the tin is removed by filtering. The precipitate from ammonia (Fe) is also calcined, fused with pyrosulphate, treated with tartaric acid; then traces of tin are removed with hydrogen sulphide and iron sulphide is precipitated with ammonia. The precipitate is filtered, dissolved in hydrochloric acid, acidified with nitric acid and iron is precipitated in the form of the hydrate which is calcined; then Fe_2O_3 is weighed. The filtrate from iron sulphide is added to filtrate I from tin, i. e., to the main mass of Nb, Ta, Ti, Zr. After freeing from hydrogen sulphide the solution is acidified with sulphuric acid and precipitated in the cold with kupferon. The precipitate is carefully dried, calcined and weighed. Then it is fused with pyrosulphate and the fused mixture is lixiviated in the crucible with a 1 per cent solution of tannine in a 10 per cent solution of hydrochloric acid (6). The solution is poured out into a beaker, and the crucible is rinsed with water a few times. A reddish precipitate sticks stubbornly to the walls of the crucible; it should be rubbed several times with a damp piece of filter paper, or left for calcining the joint precipitate of niobium and tantalum afterwards. The solution with the tannine precipitate is boiled and allowed to stand on a water bath for 2—3 hours or all night. The precipitate is filtered, washed with the tannine reagent, calcined, and then the sum $Nb_2O_5+Ta_2O_5$ is weighed. The filtrate is acidified with sulphuric acid and precipitated with kupferon, filtered, carefully dried, calcined and then ZrO_2+TiO_2 is weighed. Then it is fused with pyrosulphate, lixiviated with suplhuric acid and hydrogen peroxide, and titanium is determined calorimetrically. The solution is transferred into a beaker, sulphuric acid is added up to 10 per cent by volume and zirconium phosphate is precipitated with ammonium

phosphate. This is left standing several hours or over night. Then it is filtered carefully, after which zirconium phosphate is weighed.

Niobium and tantalum pentoxides are fused with pyrosulphate, lixiviated with oxalic acid and tantalum is separated with tannine after Schoeller's method (Lendelle and Hillebrandt, p. 519). In the filtrate niobium is precipitated with ammonia.

Both calcined precipitates of niobium and tantalum pentoxides should be tested for silica by evaporating with sulphuric and hydrofluoric acids. Tannine precipitates always contain silicon not entering into the composition of cassiterite.

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PHYSIOLOGY

AN ATTEMPT TO ANALYZE THE SYMPTOMS OF POLYNEURITIS IN VITAMIN B_1-DEFICIENCY IN THE LIGHT OF THE CHEMICAL THEORY OF THE NERVOUS PROCESS

By Ch. S. KOSHTOJANZ, Corresponding Member of the Academy

Modern biochemical investigation has shown the normal cellular process of carbohydrate decomposition to be directly dependent on the vitamin B_1. Namely, in the absence of vitamin B_1 there sets in a sharp delay in the further oxidation of the pyroracemic acid and of its salt (pyruvates) already formed. This results in an accumulation of pyroracemic acid in the cells, which is followed by a toxic effect (1).

Lohmann has shown by direct experiments that vitamin B_1, combining with phosphoric acid, passes into the form of an ester of the pyrophosphoric acid which is a co-ferment of carboxylase, i. e., a co-carboxylase.

A more close investigation shows that the pyrophosphoric ester of the vitamin B_1 is a specific co-ferment of the dehydrogenase of the pyroracemic acid.

Data, pointing to the vitamin B_1 being involved in the cellular processes of carbohydrate decomposition, have been secured from studies of the respiration of the tissues of normal pigeons and of those fed on a B_1-deficient diet, in particular, by studying their brain tissue. In a normal brain tissue one never succeeds in detecting any appreciable amount of pyruvates, while in the absence of vitamin B_1 pyruvates are formed in it in considerable quantities. On the ground of what has been said above, it is easy to see the cause of this phenomenon in the deficiency of carboxylase. The introduction of vitamin B_1 into the brain tissue of pigeons fed on a vitamin B_1-deficient diet leads to the oxidative break up of the pyruvates.

It proved possible to detect appreciable amounts of the products of hindered carbohydrate decomposition—lactates and pyruvates—in the blood of vitamin-deficient animals (pigeons, rats). The toxic effect observed in the so-called acute polyneuritis and which is the expression of the organism suffering from vitamin B_1-deficiency, is accounted for by the accumulation of these substances in the blood. An accumulation of these products of carbohydrate decomposition during acute polyneuritis has been observed in the brain tissue, too. It should be noted, however, that a mere introduction of, say, lactates into the blood-circulation, fails to provoke the typical symptoms of acute polyneuritis. Hence it follows that it is impossible to explain the symptoms arising in the case of vitamin B_1-deficiency by a mere accumulation of the products of an incomplete carbohydrate oxidation. Inasmuch as the main symptoms of the disease consist in disturbances of the function of the nervous system, one may assume that the delayed decomposition of

carbohydrates at the phase of pyroracemic acid leads to the disturbance of some chemical processes which are specific for the normal function of the nerve cells. In the first place it seems worth to indicate that in the nerve cell such a specific process is the synthesis of acetylcholine-like substances which, according to modern views, directly participate in the acts of nervous stimulation.

As shown by recent biochemical and physiological investigation ([2],[3]), the synthesis of those acetylcholine-like substances in the nerve cells and in nerve terminals is intimately connected with the products of carbohydrate metabolism, in particular, with pyruvates and lactates. It is to mean that choline which is present in these cellular formations, combining with the products of carbohydrate metabolism in which a certain ferment (choline-esterase) is involved, is transformed into physiologically highly active choline esters (pyruvate-choline, acetylcholine, etc.). This problem has been treated in detail by the author and his collaborators in their previous papers published in this periodical ([3], [4], [5]).

Thus, the accumulation of pyruvates and lactates, which is found to attend vitamin B_1-deficiency, may, among other results, lead to a sharp disturbance of the level of the synthesis of acetylcholine-like substances.

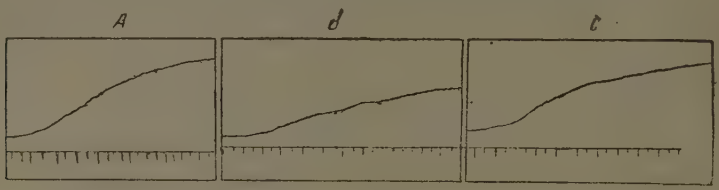

Fig. 1. Effect of extracts from the skeletal muscles of normal and vitamin B_1-deficient pigeons on the dorsal muscle of a leech.
A and *C*—vitamin B_1-deficient pigeons, *B*—normal pigeon.

The disturbance of the normal process of the synhtesis and decomposition of acetylcholine-like substances may be one of the essential causes of the disturbance of the functional connexion between the nervous system and the rest of the organism. The accumulation of acetylcholine-like substances, as seen from direct experiments, is exerting an inhibitory effect both upon the central nervous system and on the functions of other organs. An excess of acetylcholine-like substances disturbs the normal course of transmission of stimulation from the motor nerves onto the muscles; it slows down markedly the rythm of the heart, provokes alterations in the motor function of the intestinal tract, etc.

And indeed, we see that the chief symptoms of the disease of both man and animal in the case of vitamin B_1-deficiency concern the nervous system. These are the general symptoms of polyneuritis, accompanied by phenomena of paralysis, by the loss of the normal function of neuromuscular control, loss of reflexes and, on the basis of all these, by the loss of the ability of co-ordinate movements. All this, considered as a whole, made us assume the existence of a close dependence between the chemical basis of the main symptoms of polyneuritis caused by vitamin B_1-deficiency, and the chemical processes of the formation of substances which are involved in the acts of the nervous activity. The substratum of this dependence is the cellular carbohydrate metabolism which is the first to suffer from vitamin B_1-deficiency, the synthesis of the choline esters in the elements of the nervous system being bound with definite links of this carbohydrate metabolism.

I chose these assumptions as point of departure for the experimental work carried out by me and my co-workers. This experimental research is logically bound with the bulk of our work in which we have shown the intimate connexion existing between the formation of acetylcholine-like substances and the normal cycle of cellular carbohydrate metabolism.

Two series of experiments with pigeons fed on polished rice were arranged by us. After typical polyneuritis symptoms have set in, we examined a number of organs (brain, heart, intestine, muscle) of vitamin B_1-deficient pigeons both for their acetylcholine content and their ability to synthetize acetylcholine in vitro; the data obtained were compared with those secured from similar tests with normal pigeon organs. The extracts from the above organs were prepared according to the method of Chiang and Haduum. The determinations were made on a biological test-object—the dorsal muscle of a leech.

In so far as the brain and intestinal tissues are concerned (experiments made in collaboration with Artemov and Mitropolitanskaya), we failed as yet to detect any essential difference between the amount of acetylcholine in vitamin B_1-deficient pigeons as compared with normal ones. It should, however, be kept in mind that the initial amount of acetylcholine in these organs is so large in normal animals, too, that the biological method available permits of no precise solution of this quantitative problem. Perfectly clear results have been obtained with respect to the skeletal muscle (experiments in collaboration with A. M. Riabinovskaya). It was found that the quantity of acetylcholine in the muscles of the vitamin-deficient pigeons is, as a rule, considerably higher compared with that in the muscles of normal birds. The results of these experiments are represented in the cymogram (Fig. 1).

The experiments made on muscles thus yielded evidence in support of our theoretical hypothesis as to the processes underlying the disturbance of the neuro-reflectory processes in the case of vitamin B_1-deficiency. The lack of vitamin B_1 (co-carboxylase) leads to a disturbance in the decomposition of carbohydrates, arresting it at the phase of the pyroracemic acid, and this, in its turn, leads to the disturbance of the normal level of the synthesis of the chemical factors of the nervous process, in particular of acetylcholine, the latter resulting in the disturbance of the normal process of nervous regulation.

Our investigation of the ability of the brain tissue of normal and vitamin B_1-deficient pigeons to synthetize acetylcholine in vitro are in progress.

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GENETICS

LAW OF INCREASE IN SIRE EVALUATION RELIABILITY WITH INCREASE IN OFFSPRING NUMBER

By W. E. ALTSCHULER

(Communicated by N. I. Vavilov, Member of the Academy, 13. V. 1939)

The American geneticist and selectionist Sewall Wright in his paper entitled «On the evaluation of dairy sires» (1) has shown that the selection significance of deviations from average records of daughters should be taken to be of different importance according to the number of offsprings which were used to obtain the data in question. For example, the deviation of milk productivity record equaling 500 kg when determined for 10 daughters, is by far more significant than the same deviation determined for two daughters only. It stands to reason that the deviations of economical characters from the average of the breed have different significance under different conditions of menagement and within different breeds. Proceeding from general positions of genetics and making use of mathematical analysis, Wright has shown that the selection significance of deviations varies according to $\frac{n}{n+2}$, where n is the number of daughters which served to establish the given record, and 2 is a constant true when the expression of the genotypical qualities of the cows is complete, and the correlation of mother—daughter is consequently equal to 0.5.

As a rule, however, the expression of hereditary qualities is never complete. According to Wright, the above constant may be determined for a given breed and under definite conditions by the method of path coefficients, due account being made of the value of the correlation coefficient between the productivity records of mothers and daughters.

Gowen has determined the value of this constant for three American breeds: Jersey, Holstein-Frisian and Guernsey as being equal to 6.2. In this case Gowen proceeded from the mother-daughter correlation coefficient for milk productivity which for these breeds shows an average of 0.35.

This method of determination may practically be adopted only when 1) dams and daughters are not correlated by the same conditions of menagement and 2) these conditions do not differ materially. However, the above correlation is often rather considerable. Besides, the conditions of menagement of dams are sometimes very different from those of daughters. In this country the improvement of conditions of menagement is in rapid progress; the expression of genotypical variability and hence both the trend and the efficiency of selection may therefore largely differ for mothers and daughters, being mostly more favourable for the latter. For this very reason the appli-

cation of the above method of determination of the constant is mostly unpracticable under our conditions.

It is obvious that the value of the constant in Wright's coefficient must be connected with the magnitude of the correlation variability of daughters, the latter in its turn being determined by the community of father. This variability was determined in our previous works with regard to milk productivity, body weight and butterfat percentage for the Simmenthal cattle of the Sychev nursery ([2], [3]). The relative value of this variability in per cent to the general variability of phenotypical records of bulls for different numbers of daughters is shown in Tables 1, 2 and 3.

If we adopt the phenotypical variability of the average bull records for any number of offsprings being equal to 100, then, multiplying 100 by the corresponding value of the given coefficient, we should obtain the magnitude of the above correlative variability for the given number of offsprings. Consequently, the equation takes the form $100 \cdot \frac{n}{n+X} = \%$ of correlative variability of daughters depending on the community of father. And hence, on the contrary, knowing the magnitudes of the correlative variability we are able to determine the mentioned constant. It is important that the magnitudes of the constant may be determined by means of many analogous equations for different number of offsprings. Thus, we can determine whether or not the magnitude X is a really constant value for different numbers of offsprings. The constancy of X obviously will serve as an experimental confirmation of Wright's statement, on the one hand, while on the other hand it will serve as an experimental control of the method of determination of correlative variability suggested in our following (p. 364) work. For this purpose the following equations have been composed (Table 1).

Table 1

Determination of the Value Constant in Wright's Coefficient of Sire Evaluation Reliability

Number of daughters	Relative value of correlative variability of daughters depending on father community	Determination of the value of the constant
2	27.02	$27.02 = 100.\frac{n}{n+X}$ hence $X = 5.40$
3	34.75	$34.75 = 100.\frac{n}{n+X}$ » $X = 5.60$
5	47.37	$47.37 = 100.\frac{n}{n+X}$ » $X = 5.55$
8	58.75	$58.75 = 100.\frac{n}{n+X}$ » $X = 5.60$
25	81.48	$81.48 = 100.\frac{n}{n+X}$ » $X = 5.66$
50	89.89	$89.89 = 100.\frac{n}{n+X}$ » $X = 5.62$
100	94.60	$94.60 = 100.\frac{n}{n+X}$ » $X = 5.70$

We see that the value of X in the reliability coefficient determined from experimental data on the variability of 545 sires of the Sychev nursery for

different numbers of daughters shows a very stable magnitude. The value of the constant varies but very little (beginning with 2 daughters and up to 100 and more it fluctuates within the range of 2—3 tenths). Such a stability of the constant is significant, and we shall return to this question in what follows. Besides it is of interest that the value of the constant determined by Gowen as average for three American breeds by quite a different method proves equal to 6.2, i. e., is very close to the value obtained by us for the Sychev Simmenthal cattle.

The data obtained by A. I. Bakanova as a result of an analogous investigation on butterfat percentage of the Sychev cattle are given in Table 2.

Table 2

Determination of the Value of the Constant in Wright's Coefficient of Sire Evaluation Reliability

Number of daughters	Relative value of correlative variability depending on father community	Definition of the value of the constant
2	14.87	$14.87 = 100.\frac{n}{n+X}$ hence $X = 11.45$
5	30.29	$30.29 = 100.\frac{n}{n+X}$ » $X = 11.51$
10	46.63	$46.63 = 100.\frac{n}{n+X}$ » $X = 11.45$
15	56.42	$56.42 = 100.\frac{n}{n+X}$ » $X = 11.58$
20	63.67	$63.67 = 100.\frac{n}{n+X}$ » $X = 11.75$
30	72.54	$72.54 = 100.\frac{n}{n+X}$ » $X = 11.22$
50	81.49	$81.49 = 100.\frac{n}{n+X}$ » $X = 11.36$
100	89.75	$89.75 = 100.\frac{n}{n+X}$ » $X = 11.42$

In this case, too, the exceptional stability of the value of the constant is quite manifest.

650 sires were evaluated by the body weight of calves. In this case we made use of the data of measurements of about 50 000 calves of the Sychev nursery. In one of our previous works ([2]) we found the relative value of the correlative variability of calves depending on the community of father. On the basis of those data in our present work we determined the mentioned constant for different numbers of calves (Table 3).

The regularity deduced is a result of generalization of data from about 800 collective farms, several large Soviet State economies, and more than a thousand of husbandries of collective and individual farmers. The smallest inaccuracy in the calculation of the «theoretical curve of offsprings», or of the curve of «control group of non-related animals», etc., as well as the least change introduced in the formulae of Wright, Vassin or others, results in an immediate disturbance of the given regularity observed in the stability of the constant. Such a stability of the constant in the reliability coef-

Table 3

Definition of the Value of the Constant in Wright's Coefficient of Sire Evaluation Reliability

Number of calves	Relative value of correlative variability of calves depending on father community	Definition of the value of the constant
8	31.11	$31.11 = 100.\frac{n}{n+X}$ hence $X = 13.71$
13	47.61	$47.61 = 100.\frac{n}{n+X}$ » $X = 14.31$
18	56.03	$56.03 = 100.\frac{n}{n+X}$ » $X = 14.12$
23	60.93	$60.93 = 100.\frac{n}{n+X}$ » $X = 14.74$
28	64.41	$64.41 = 100.\frac{n}{n+X}$ » $X = 15.47$

ficient obtained on a various and abundant empirical material testifies to the theoretical correctness of the applied methods of investigation and to the validity of the established regularity of the sire evaluation reliability with the increase in offspring number, the data relating to milk productivity, butterfat percentage and body weight of Sychev Simmenthal cattle.

The data obtained by us make us conclude that Wright's coefficient introduced in the formula of the evaluation of sires describes quite correctly the regularity of increase in the reliability of the evaluation. The law of increase of sire evaluation reliability may, therefore, be formulated as follows: the increase of reliability of the evaluation of sires with the growth of the number of offsprings proceeds in proportion with the value $\frac{n}{n+X}$ where n is equal to the number of offsprings and X—to a definite constant true for a given breed and conditions. This regularity is an average for a given breed and conditions of menagement, and possesses all the advantages and drawbacks inherent to average magnitudes. It holds for a definite group of sires and, naturally, for definite conditions of menagement.

The number of offsprings is a very important factor which rapidly increases the degree of reliability of evaluation. The trend of selection, however, is different under different conditions of menagement. In order to detect the most desirable and economically valuable genotypical variability of the population, it is necessary to create optimal conditions of menagement.

The law analyzed above has already been introduced into practice and applied in several directions.

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GENETICS

HEREDITARY DIFFERENCES IN SIRES AND ENVIRONMENT RESPONSIBLE FOR THE VARIABILITY OF THE AVERAGE RECORDS OF DAUGHTERS

By W. E. ALTSCHULER

(Communicated by N. I. Vavilov, Member of the Academy, 13. V. 1939)

The study of quantitative characters is one of the hardest problems in the genetics of farm animals. Milk productivity, body weight, wool productivity and other economical characters to a great extent depend both on hereditary qualities and environment. The question as to what degree the diversities of sire-records are influenced by the hereditary qualities of their fathers, and to what degree by other factors, is of prime importance in the selection of sires. It is anything but easy to solve the question whether the increase in daughter records is due to the selection of better sires, or to improved conditions of menagement, feeding, etc. In order to find adequate methods of approach, it is necessary to establish what are the factors (besides hereditary diversities) responsible for the difference in evaluation records of sires. These factors can be best of all classified as follows.

1. Diversity in menagement and keeping conditions, which may regularly influence the variability.

2. Diversity in the qualities of dams, due to individual and group-selection of dams for definite sires.

3. Casual factors (within this category are included manifold fortuitous effects of environment, influences of accidental selection of dams, etc.).

In each separate case the analysis of the influence of these factors constitutes a complicated and specific problem.

The Sychev State pedigree nursery for breeding Simmenthal cattle (Smolensk region) embraces the breeding work of about 800 collective farms and a number of State farms. Below we give an analysis of the evaluation of the sires of this nursery with regard to the character of milk productivity of their daughters. The cow-daughters of each bull are distributed among many villages and individual farms. The possibility of a similar effect produced by one and the same husbandry upon all or many daughters (the so-called intraeconomical correlation) is therefore almost excluded. However, to get entirely rid of the intraeconomical correlation, for the analysis of the records only those daughters were taken into account which had been kept at different farms. Until 1934—35 the sire of any mating post was usually mated with all the cows within the radius of its work. The records used in this analysis refer to that period. It stands to reason that individual selection of dams could exert no material effect upon the milk-records of

daughters. The influence of group-selection of dams, i. e., the fact that one sire might have worked on a better dam population, while the other on a poorer one, was checked by special investigation. The influence of other moments (diverse effects of menage and keeping conditions, casual influences of dams, etc.) was made allowance for by subsequent analysis.

In order to solve the problem as to the relative importance of inheritance and surrounding medium, we adopted the method of comparing the variability of the average records within the progeny of a given sire to that of the average records shown by non-related animals. Having determined the difference in the dispersal of the average records in both cases, it makes one able to evaluate the importance of each individual factor of variability.

Number of daughters	Relative importance of correlative variability	Relative importance of correlative variability of daughters as dependent on hereditary variability of bulls
2	13.51	27.02
3	23.40	34.75
5	37.91	47.37
8	51.35	58.75
15	67.78	72.56
25	78.23	81.48
50	88.00	89.89
100	93.66	94.60

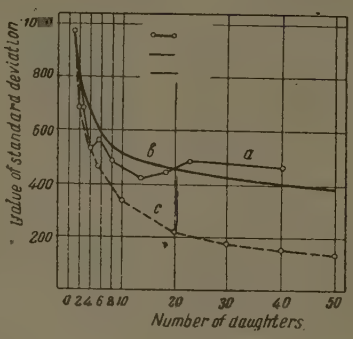

Fig. 1.

The range of variability of the average records of the bulls proves to largely vary with the number of daughters (Fig. 1). On the axis of abscissae is plotted the number of daughters, on the axis of ordinates the value of the standard deviation computed from the average records of sires in the Sychev nursery, in kg. The empirical curve *a* has been constructed on the basis of a sufficiently abundant material involving the evaluation of 545 sires by the average records of their daughters, which served also to determine the theoretically expected curve *b*. The determination of this curve was made according to the method worked out by Prof. B. N. Vassin on account of variability of average records in rams (2), and somewhat modified by us:

$$\sigma_n = \sqrt{a_1 + \frac{a_2}{n}} \qquad (1)$$

where σ_n is the standard deviation of average records with a numbers of offsprings equal to n, a_1 is the definite constant true for the given race and conditions, a_2—an other analogous constant, and n—the number of offsprings.

The theoretical curve obtained seems to coincide fairly well with the empirical one. It may therefore be taken to satisfactorily express the variability of average records in the case of a different number of daughters.

The curve of non-related cows is given in the same graph *(c)*. On the axis of abscissae is plotted the number of animals, on that of ordinates—the value of standard deviation.

It may be seen that the curve of daughters runs throughout its whole length higher than the non-related curve, and the greater the number of animals, the greater the distance between these curves. This is an uncon-

testable proof of the fact that the daughters have not been taken at random, but exhibit a definite additional variability which can be clearly seen from the diagram referred to above. This «additional variability» was shown by the analysis of distribution of daughters and of other economical conditions to depend in our case on the community of father. It was termed by us the «correlative variability of daughters». This correlative variability is not entirely excluded in the random group. Indeed, one small group of cows chosen at random may by accident prove to be composed only of cows produced by hereditary valuable sires, another group may be made up of daughters of bulls of lower quality, while the third will contain exclusively those of the worst bulls.

The part of correlative variability of daughters which is made evident by our diagram (divergence between the curve for daughters and that for the group of non-related animals) was called by us the «difference correlative variability of daughters».

We began by determining the relative value of the «difference correlative variability of daughters» in per cent to the general variability of the average records of the sires' daughters. The following formula has been resorted to:

$$\sigma^2_{\text{gener.}} = \sigma^2_{\text{non-rel.}} + \sigma^2_{\text{dif.}} \qquad (2)$$

where $\sigma^2_{\text{gener.}}$ is the square of the standard deviation of the average records of the sires' offsprings, $\sigma^2_{\text{non-rel.}}$ — the square of standard deviation of the average records of non-related animals, $\sigma^2_{\text{dif.}}$ — the square of the standard deviation of the «difference correlative variability of daughters». By means of similar equations for different numbers of daughters we determine the value of the «difference correlative variability of daughters» in per cent to the general variability of the average records of daughters (see table, column 2).

Next it was established that the part of the correlative variability which is expressed by the «difference correlative variability» is equal to

$$1 - \left(\frac{1}{\sqrt{n}}\right)^2 \qquad (3)$$

where 1 is equal to the general correlative variability of daughters and n — to the number of daughters. The relative values of the general correlative variability due to hereditary differences of sires were found for different numbers of daughters in per cent to the total variability of the daughters' records.

These values were found with the help of the «difference correlative variability» and formula (3).

This method of evaluating the relative value of different factors of variability proved to find full evidential support when applied to practice. Thus, formula (2) in a somewhat modified form was used by Wright (1932) to establish the law of increase of reliability of sires' evaluation with the increase of the number of offsprings. One of the most important practical conclusions drawn from this work is the following.

The differences in the average records of daughters of the best and the worst sires amount to 1100—1300 kg of yearly milk productivity, even when calculated from a rather considerable number of daughters (1570). We have demonstrated that these differences depend to a large degree on the hereditary diversities of the sires. This seems to be most promising with regard to further improvement of the hereditary and productive qualities of the progeny by selecting the best sires. The use of the best sires must be

particularly efficient when combined with the selection of dams, whose appurtenance to one or other line should be taken into account.

The introduction of formula (2) encounters severe criticism on the part of some authors. It found, however, a brilliant confirmation when applied to practical work, while no other formula proved valid. For practical verification of formula (2) and other methods used see [1].

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GENETICS

COLCHICINE-INDUCED TETRAPLOIDY IN *HELIANTHUS ANNUUS* L.

By V. A. RYBIN

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Representatives of the *Compositae*, when treated with colchicine, readily give chimeral shoots with tetraploid tissue and flowers with large (polyploid) pollen. In a paper published as early as at the end of 1937 (1) Blakeslee cited among plants reacting in this way to colchicine treatment one member of the *Compositae*, *Cosmos*. In a second list, published by Blakeslee's laboratory (2), of plants having given as a result of colchicine treatment progeny with a doubled chromosome number, there are included three representatives of the *Compositae*: *Cosmos*, *Bidens* and *Rudbeckia*. Moreover, colchicine-induced tetraploids have been obtained in *Zinnia* by Morrison (3) and in *Taraxacum* by Kostoff and Tiber (4).

For his experiments on obtaining tetraploids by the colchicine method the writer chose, among representatives of the *Compositae*, *Helianthus annuus* L.—an oleiferous variety of the Saratov Experiment Station, No. 169. The sunflower proved very responsive to colchicine treatment. In carrying out these experiments two methods were followed: 1) application of a drop of colchicine solution on the tip of the stem and 2) immersion of young plants in such a solution.

In the first case, i. e., when drops of colchicine solution were applied to the tip of the stem where they were well retained in the hollow formed by the young leaflets, after about two days the effect of colchicine could already be noticed. At first, it was expressed only in paling of the smallest leaflets and of the base of the larger ones. Later on, a retardation in growth could be observed, and the developing leaves acquired a very peculiar aspect: their blades were deformed, having irregular contours; the flesh of the leaves between the veins became covered with blister-like swellings, giving the leaves a wrinkled, rumpled appearance; the colour of the leaves became perceptibly darker. Drops of 0.05 and 0.1% solutions of colchicine were applied each evening for 8 days. Then the plants were allowed to develop freely without any further inteference on the part of the experimenter. Such plants flowered and produced normal heads. In plants thus treated no large pollen grains were found.

The immersion of the plants in a colchicine solution had a considerably stronger effect. Four young sunflower plants (at the stage of the first six leaves) were immersed in a 0.05 per cent colchicine solution and kept in it until the following day, the temperature being from 20 to 25° C. Prior to

immersion, the first pair of leaves of all the four plants was cut (either the tips were cut off at an acute angle to the midrib, or several slits were made between the veins of the second order). Five days after immersion all of the four plants changed their appearance in a characteristic manner (Fig. 1). The second and third pair of leaves acquired a wrinkled, blistery aspect. Owing to irregular growth, their edges became wavy. The leaf blades became bent like a bow convex on the upper side. The stem became noticeably thickened toward the tip. During the next 10—15 days the plants almost completely ceased growth; the leaves, particularly the young ones, perceptibly paled, and it seemed that the plants would not be able to recover. However, the main stems subsequently resumed their growth, and about a month after immersion in the colchicine solution the formation of inflorescences could clearly be seen on the tips of the main stems of all the four plants. By this time the stem had a very strange aspect: gradually thickening toward the

Fig. 1. Right—plant No. 1 (Saratov oleiferous sunflower No. 169) 5 days after immersion in colchicine solution; left—control.

Fig. 2. Deformed, fasciated sunflower head (Saratov No. 169) on the main stem of plant No. 1.

top, at a certain height it attained a maximum thickness, and then again became thinner toward the very tip, which gave it the appearance of an elongated spindle.

At the same time as the inflorescences started to develop on the main stems, axilliary shoots began to make their appearance from the axils of the lower, often deformed leaves with the parenchyma between the veins covered with blister-like swellings. By the end of July, i. e., approximately two months after the plants had been immersed in the colchicine solution, the main stems began to flower. The inflorescences of the main stems were extremely deformed (Fig. 2). Plant No. 1, shown in Fig. 2, had at the tip of its stem not a normal head but a ball-shaped one, which, upon close inspection, was found to be composed of 7—8 small, deformed heads grown together into a single head. The ray florets in each of such heads were deformed and of unequal size. In addition to ray and disk florets, such ball-shaped fasciations bore deformed, unequally developed involucral bracts and even deformed leaves. The examination of the pollen under a comparison microscope showed that the flowers in fasciated inflorescences contained pollen grains twice or four times as large as those of the control plants (Fig. 3). Three of the plants which flowered at the same time and had deformed, fasciated inflorescences and large pollen grains were pollinated inter se by transferring the pollen with the aid of a feather, by plucking out the anthers and touching

with them the stigmas, or by bringing into contact entire inflorescences. The fourth plant flowered somewhat later and was not artificially pollinated. The inflorescences were not bagged.

The heads of the main stem of three of the four deformed plants flowered and dried up without setting any seed at all. The head of plant No. 1 set a single seed, which was abnormal in structure. Instead of two ribs it had four, giving the impression of two seeds grown together. In place of bilateral symmetry, it displayed radial symmetry. The kernel in cross-section was not flattened as usual, but round.

Six days after the main stems had flowered the lateral axilliary shoots began to flower, which by this time had grown beyond the main stem, giving to the plants a peculiar candelabra-like appearance. In some of the plants, cracks began to appear at about this time running along the thickened,

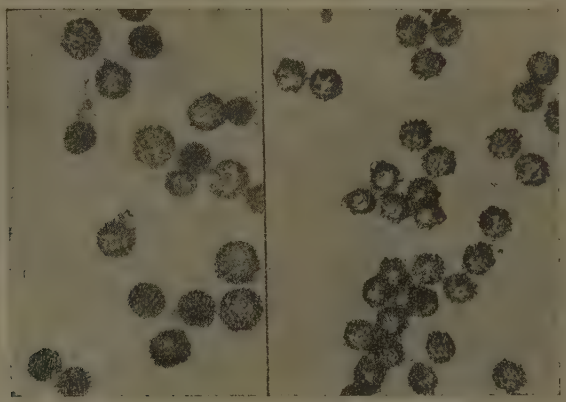

Fig. 3. *Helianthus annuus* pollen; left—of plant No. 1; right—of control plant. Viewed in a comparison microscope.

spindle-like portion of the stem, pointing, in all probability, to a great mechanical pressure of the inner tissues of this part of the stem. Special callus-like tissue formed from within and soon covered these cracks.

The axilliary shoots which were formed in considerable number bore normally appearing leaves. The strongest of these shoots bore heads some of which were normal, while others exhibited asymmetry, expressed in an unequal development of the ray florets. On a single head there were not only sectors bearing large ray florets, but also sectors bearing smaller, not fully developed ones, sometimes irregular in shape.

An examination of the pollen showed that some of the heads had pollen grains of normal size, while in others the pollen grains were twice or even four times the normal size. Close inspection showed that in such heads there are often disk florets having a larger number of lobes in the corolla than it is normally the case. Heads having large (polyploid) pollen were labelled. The heads were not bagged, and the flowers were not artificially pollinated with the large pollen. All the heads set seed under conditions of open pollination. While harvesting the heads from the experimental plants, the writer's attention was attracted by the unequal size of the seeds from one and the same head and their asymmetrical arrangement within the head. Often in a single head there were patches of unusually large seeds separated from other patches of smaller seeds by a strip of florets that had not set seeds at all (Fig. 4). In other cases large seeds were found immediately adjoining

smaller ones, and so on. It should be noted that this phenomenon was observed only in heads which at the time of flowering had been found to possess large pollen grains. This gives grounds to assume that such heads are chimeral in structure and consist of sections of tissue differing in chromosome number. To check this assumption, large and small seeds from different sections of the heads were kept separately when harvested.

Without waiting for the regular spring sowing, the writer germinated the single seed that had set on the main stem of plant No. 1 (see above). The seed kernel was first taken from its shell and then placed on moist filter paper. The next day the seed germinated, and it was sown in a pot. A count of the chromosomes in the primary root, fixed with Navashin's chrom-aceto-formalin solution (10 : 4 : 1), showed that the seedling had a tetraploid chromosome number—68. In distinction from diploid seedlings, this tetraploid had rounded pyriform cotyledons.

The fact that a tetraploid seedling was obtained from the seed from the main stem of plant No. 1 gives grounds for expecting that some of the seeds obtained from the heads of the axilliary shoots of this same plant that had large pollen may also give polyploid seedlings. Tetraploid sunflowers obtained as a result of chromosome doubling in the standard oleiferous variety No. 169, may prove to be valuable material for clearing up the problem as to changes in the rate of oil accumulation in *Helianthus* when the chromosome number is doubled. A priori, it may be expected that the oil-content of diploid and tetraploid forms will not be identical. Such an assumption finds support in literary data on the changes in the biochemical properties of plants induced by chromosome doubling*.

Fig. 4. Ripe head from one of the axilliary shoots of a sunflower plant that had been subjected to colchicine treatment. Lower left—patch of large seeds; upper right — of small seeds; between them a sterile area.

The tetraploid *Helianthus annuus* may also be of interest in the work on crossing the sunflower with the Jerusalem artichoke (*Helianthus tuberosus* L.). The latter species is a hexaploid. Shchibra ([6]) succeeded in obtaining a 68-chromosome sunflower-artichoke hybrid of considerable practical interest. Crosses between tetraploid sunflowers and this hybrid and also between tetraploid sunflowers and hexaploid *Helianthus tuberosus* are of great interest from a cytogenetic point of view, inasmuch as the problem of auto- and allo-syndesis in the case of interspecific crosses in the genus *Helianthus* has not yet been thoroughly studied. Moreover, the elucidation of these problems for the genus *Helianthus*, which includes two important crop plants and is characterized by a polyploid series of species, may yield interesting practical results.

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GENETICS

LETHALITY OF GAMETES AS DEPENDENT ON THE EXCHANGE OF SEGMENTS BETWEEN PARTLY HOMOLOGOUS CHROMOSOMES IN A *NICOTIANA* SPECIES HYBRID

By DONTCHO KOSTOFF

(Communicated by N. I. Vavilov, Member of the Academy, 8. VI. 1939)

While studying the percentage of viable pollen in the species hybrid *N. glauca*×*N. Langsdorffii*, I found their percentage approximately to correspond to that of dyad and monad microspores formed in the hybrid as a result of non-occurrence of the first or both meiotic divisions (1). The study of pollen viability in the species hybrids *Nicotiana Raimondii* ($n=12$) ×*N. tabacum* var. *Tyk-kulak* ($n=24$) in connexion with the formation of the dyad and chromosome conjugation during meiosis has led to quite different results. This hybrid, grown in the green-house, usually formed at the end of April 3—6 bivalents. Pollen mother cells with 2 bivalents and with more than 6 were rarely found (ca. 6%). At the same time microspores were found in about 12—15% of the PMC dyad. They were usually due to the non-occurrence of the first meiotic division (i. e., restitution nuclei). When the flowers opened and the anthers dehisced, no viable pollen was found. This was indicative of the fact that both kinds of pollen grains: 1) those having reduced nuclei, as well as 2) those having non-reduced nuclei (dyads) with the total chromatine material from *N. Raimondii* and *N. tabacum* (36 chromosomes*), were lethal. The lethality of the first kind of pollen originating from reduced microspores has been usually interpreted by assuming an irregular distribution of the hereditary substances during meiosis and the formation of tetrad microspore nuclei with uncomplete and unbalanced genomes. The pollen grains originating from dyad microspores have two complete genomes, the whole *Raimondii* genome and the whole *tabacum* genome and yet they were lethal. The non-viability of these pollen-grains could neither be due to the loss of some chromosome fragments as a result of crossing-over in inverted region or regions, since single chromatine bridges were very rarely observed during the meiosis (in 0.3% of the pollen mother cells). The most probable cause of their lethality is the exchange of segments between partly homologous chromosomes, which takes place in each pollen mother cell between 3—6 partly homologous chromosome pairs (bivalents) following chiasma formation. The plausibility of this assumption is supported by the behaviour of the same hybrid plants during the autumn

* Some of the chromosomes, however, should not be identical with the chromosomes of the parental species, because exchanges of segments (crossing-overs) have taken place between partly homologous chromosomes at the «four-strand stage».

(1938) when their meiosis proceeded at a lower temperature. Under these conditions the hybrid usually formed 0.4% of bivalents, having in about 18% of the pollen mother cells dyad microspores; ca. 5% of the PMC showed asyndesis (no bivalents). By this time the hybrids were forming about 0.4% of viable pollen grains. These pollen grains probably developed from PMC with asyndesis in which the first meiosis has failed, thus producing dyad microspores and further pollen with whole chromosome sets and unchanged chromosomes of the parental species *N. Raimondii* and *N. tabacum*. It should be mentioned here that these two species are not closely related. They belong to two different sections—the former to *Rustica* section and the latter to *Tabacum* section.

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GENETICS

DEVELOPMENT OF POLLEN AND EMBRYOSAC IN INTERSPECIFIC HYBRIDS OF *TARAXACUM*

By V. PODDUBNAJA-ARNOLDI

(Communicated by N. I. Vavilov, Member of the Academy, 28. IV. 1939)

Quite recently two rubber-yielding species of *Taraxacum* were discovered in this country, viz., *T. kok-saghyz* Rod. and *T. hibernum* Stev. The genus *Taraxacum* gained in importance after this discovery. Besides, this genus is of interest, owing to the fact that many species belonging to it, *T. hibernum* included, are characterized by asexual propagation. The type of asexual propagation found here refers to the unreduced parthenogenesis, i. e., the development of the embryo occurs without fertilization, from an unreduced egg-cell. At the present time a number of scientists ([2],[5]) have studied over 50 species of *Taraxacum*; it has been found that the great majority of them propagate asexually, normal sexual reproduction being as yet found only in 10 species, *T. kok-saghyz* included. Parthenogenesis in *Taraxacum* is intimately connected with polyploidy: all the species normal with regard to sex have 16 diploid chromosomes, whereas all the parthenogenetic ones have polyploid numbers: 24, 32, 40, 48, the majority of them having 24 chromosomes, i. e., being triploid. The problem of asexual propagation is of great theoretical and practical importance, since, on the one hand, it bears on the problems of species formation and evolution and, on the other, to stabilization of new forms through production of homozygous (in the case of reduced parthenogenesis) and constant heterozygous (in the case of the other types of asexual propagation) forms.

In order to throw light on the character and causes of asexual propagation and on the possibility of producing parthenogenesis artificially I have arranged various experiments, in the first line, on remote hybridization, since a number of authors [Ernst ([1]), Holmgren ([3]), Winge ([6]) and others] believe various forms of asexual propagation, parthenogenesis included, to be the direct result of hybridization.

The results obtained from interspecific hybridization in *Taraxacum* are briefly presented below. The work was conducted in contact with an analogous study made by V. Kovaleva; I dwelt in more detail on the cyto-embryological study of the parental species and hybrids, while V. Kovaleva ([4]) was more concerned with external morphology.

The following crosses were made by me: 1) *T. kok-saghyz* × *T. multiscaposum*, 2) *T. multiscaposum* × *T. kok-saghyz*, 3) *T. kok-saghyz* × *T. serotinum*, 4) *T. serotinum* × *T. kok-saghyz*, 5) *T. kok-saghyz* × *T. bessarabicum*, 6) *T. multiscaposum* × *T. serotinum*, 7) *T. multiscaposum* × *T. bessarabicum*,

8) *T. kok-saghyz* × *T. brevicorniculatum*, 9) *T. kok-saghyz* × *T. officinale*, 10) *T. kok-saghyz* × *T. hibernum*.

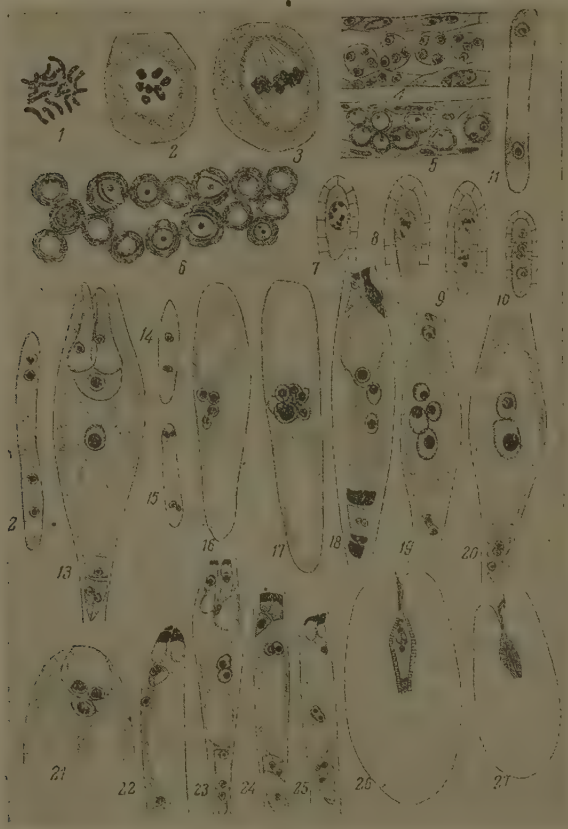
The three latter pollen parents belong to parthenogenetic forms, whereas all the remaining are normal with regard to sex. Hybrids were obtained from the first 7 combinations only. It has been shown that species which are sexually normal cross well with one another and readily produce hybrids; while normal species cannot be crossed with parthenogenetic ones irrespective of the direction of the cross. When a parthenogenetic species is used as the pollen plant, the failure is obviously due to the great or even full sterility of pollen of the parthenogenetic forms; when a parthenogenetic form is taken as mother, the failure depends on the fact that the embryos are formed in parthenogenetic species very early, prior to anthesis, so that at the moment of anthesis the embryosacs contain multicellular embryos, instead of egg-cells capable of fertilization. Although hybrids between sexually normal species of *Taraxacum* with equal chromosome numbers are readily produced, they are nearly sterile; this points to a strong genetic divergence of the species in question. Externally in the majority of cases the hybrids were intermediate between their parents. As to the character of reproduction, all of them proved to reproduce sexually and showed a chromosome number identical to that of their parents—16 (Fig. *1*). Interspecific hybridization in *Taraxacum* thus failed to produce hybrids with aberrant chromosome numbers, nor hybrids displaying parthenogenetic propagation. All the hybrids were subjected to cyto-embryological investigation which yielded similar results. I shall dwell upon the more interesting ones which were studied in more detail, namely, upon the hybrids obtained from the crosses:

1) *T. kok-saghyz* × *T. multiscaposum* and 2) *T. kok-saghyz* × *T. serotinum*. The first hybrid is of interest on account of its likeness with one of the dandelions growing as weed at plantations of *T. kok-saghyz*, which made V. Koroleva ([4]) conclude that this dandelion is a spontaneous hybrid between *T. kok-saghyz* and *T. multiscaposum*; the second species occurs in natural populations at the borderline of the areas of the two species which are endemics of the Kazan district of the Alma-Ata region. The second hybrid was interesting by having all organs, inflorescences and florets of a very large size resembling rather *T. serotinum* than *T. kok-saghyz*. Thus, for example, while the diameter of the inflorescence in *T. kok-saghyz* is from 25 to 30 mm and in *T. serotinum*—50 mm, that of the hybrid *T. kok-saghyz* × × *T. serotinum* is equal to 40—45 mm.

While studying the development of the pollen and embryosacs of the hybrids, I established that reduction division proceeds quite normally in spite of the genetic divergence of the species crossed (Figs. *2*, *3*, *7—9*). Owing to a normal conjugation of the chromosomes 8 normal bivalents and normal tetrads of micro- and macrospores are formed (Figs. *4*, *10*); at later stages, however, probably owing to genetical and physiological disharmony, the majority of pollen grains (Figs. *5*, *6*) and embryosacs (Figs. *14—25*, *27*) die. As a result of this, the hybrids prove almost fully sterile, in spite of the regular chromosome conjugation.

Growth and division of the cells and nuclei of the pollen and embryosac of the hybrids gradually cease, the contents of the cells shrink and decompose, pollen often becomes empty (Fig. *6*), instead of the embryosac nothing but a dark trace is often to be found within the ovules (Fig. *27*). The study of embryosacs has often shown: an arrest of development and degeneration of the embryosacs at the 2—4 nucleate stage (Figs. *14—15*), the absence of polarity and of normal differentiation of their elements (*16—20*), a change in the total number of nuclei and cells due to the fusion of some of them and to the failure to divide of others (Figs. *17—21*); partial or complete degenera-

tion of the egg-apparatus in the 8-nucleate embryosac (Figs. *22—25*), etc. In the hybrid *T. multiscaposum* × *T. serotinum* there was often observed death



Hybrid *T. kok-saghyz* × *T. multiscaposum*

1—Equatorial plate, ×3500. *2*—First meiotic metaphase from a pollen mother cell, × 3500. *3*—Same. *4*—Pollen tetrads, ×1300. *5*—Normal binucleate pollen as compared with degenerating one, ×800. *6*—Normal three-nucleate pollen and degenerating one, × 800. *22*—Upper part of an embryosac with degenerating egg-apparatus, ×1300. *23*—Embryosac with degenerating egg-cell, ×1000. *24*—Embryosac with degenerating egg-apparatus, × 1000. *25*—Same, × 1000. *26*—Ovule with a normal embryosac, × 200. *27*—Ovule with remnants of degenerated embryosac.

Hybrid *T. kok-saghyz* × *T. serotinum*

7—Diakinesis in the macrospore mother-cell, × 800. *8*—First meiotic metaphase in a macrospore mother-cell, × 800. *9*—Second meiotic metaphase in a macrospore mother-cell, × 800. *10*—Tetrad of macrospores, × 800. *11*—Normal 2-nucleate embryosac. × 1000. *12*—Normal 4-nucleate embryosac, × 1000. *13*—Mature normal embryosac, × 1000. *14*—Degenerating 2-nucleate embryosac, × 1000. *15*—Degenerating 4-nucleate embryosac, × 1000. *16*—Sac of polarity in a 4-nucleate embryosac, × 1000. *17*— Sac of polarity in an embryosac which contains 7 nuclei instead of 8, × 1000. *18*—Abnormal embryosac with 6 nuclei, ×1000. *19*—Same, × 1000. *20*—Abnormal embryosac with 5 nuclei, ×1000. *21*—Abnormal binucleate egg-cell, ×1000.

of pollen prior to separation of the tetrads into individual microspores. Not only the whole pollen died here, but the entire tissue of the anther owing

to which the flowers of this hybrid became unisexual, i. e., purely female. Such an extreme form of sterility was, however, of exceptional occurrence. Usually the flowers of the hybrids were bisexual and of quite a normal appearance, although the proportion of fertile pollen and embryosacs was extremely low. The percentage of normal 3-nucleate pollen grains (Fig. *6*) by the time of anthesis was on the average equal to 4.—5; that of normal 8-nucleate embryosacs (Figs. *13*, *25*) equaled 9—10, while the percentage of seeds formed was as low as 2—3. The latter circumstance being due to the fact that, alongside of degeneration of pollen and embryosacs there occurs in hybrids degeneration of fertilized egg-cells and embryos at early stages of development; however, this will be treated elsewhere.

The occurrence of nearly complete sterility in hybrids, the lack of parthenogenetic propagation which would otherwise lead to stabilization of new forms, lower rubber content [following V. Koroleva ([4])], as compared with *T. kok-saghyz*, make one conclude that distant hybridization is hardly advisable in breeding *T. kok-saghyz*.

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GENETICS

ON HYBRIDIZATION BETWEEN *TRITICUM* and *ELYMUS*

By V. PODDUBNAJA-ARNOLDI

(Communicated by N. I. Vaviloo, Member of the Academy, 28. IV. 1939)

Attempts to cross various species of *Eincorn*, of hard and soft wheats with species of *Elymus* were repeatedly made at the Department of Interspecific Hybridization of the Institute of Genetics. However, they remained as yet unsuccessful. In order to find out the cause of this failure embryological material was collected in the following crosses:

1. *Tr. aegilopoides*×*E. arenaris*, 2. *Tr. aegilopoides*×*E. multicaulis*, 3. *Tr. dicoccum*×*E.canadensis*, 4. *Tr. dicoccoides*×*E. arenarius*, 5. *Tr. dicoccoides*×*E. multicaulis*, 6. *Tr. Timopheevi*×*E. araliensis*, 7. *Tr. Timopheevi*×*E. canadensis*, 8. *Tr. vulgare*×*E. arenarius*, 9. *Tr. vulgare*×*E. dahuricus*, 10. *Tr. vulgare*×*E. multicaulis**.

The material was collected at the fields of the Institute of Genetics in Moscow, between the end of June and the beginning of July 1, 2, 3, 4, 5, 7 and 10 days following pollination.

A number of students have established the fact that species of *Triticum* and *Elymus* possess a series of embryological characters which are typical of other representatives of *Gramineae*; their pollen is three-nucleate, the type of pollen formation is successive, the embryosack develops from the lowest macrospore and contains a great number of antipodes (10—12 in *Elymus* and up to 30 in *Triticum*).

The processes of fertilization and development of the embryo were not studied in *Elymus*; they were repeatedly studied in *Triticum*. Double fertilization in *Triticum durum* was described by K. Sax ([5]). The development of the embryo of wheat after intraspecific pollination was studied by Modilevsky and Beilis ([3]) in *Tr. vulgare* varieties «Ukrainka» and «Zarja». The development of the embryo and endosperm was studied though incompletely by a number of foreign writers [Thompson ([4]), Katajewa ([1]), Wakakuwa ([6])] in interspecific crosses in *Triticum* and in crosses of *Triticum* species with the species of *Aegilops*. The study of the material obtained by me has shown that, in the great majority of cases, no embryo or endosperm are formed when species of *Triticum* are pollinated with pollen of *Elymus*, although fertilization takes place. Owing to the fact that we have not succeeded in observing double fertilization proper, in these crosses we had to resort to indirect evidence: increase in the size of the egg cell, of its nucleus and of the

* This material was turned over to me by Dr. Dontcho Kostoff. M. I. Linden and other workers of the Department of Interspecific Hybridization took part in collecting and partial treatment of the material.

secondary nucleus of the embryosac, destruction of the synergides, presence in the egg cell and embryosac nuclei of small nucleoli (probably originating from sperms) etc. (Figs. 9,10).

A few instances of formation of embryo and endosperm were discovered only in two combinations, viz., *Tr. Timopheevi*×*E. araliensis* and *Tr. vulgare* × *E. dahuricus*; their development was, however, much slower than in the case of pollination with own pollen. Besides, the development of the

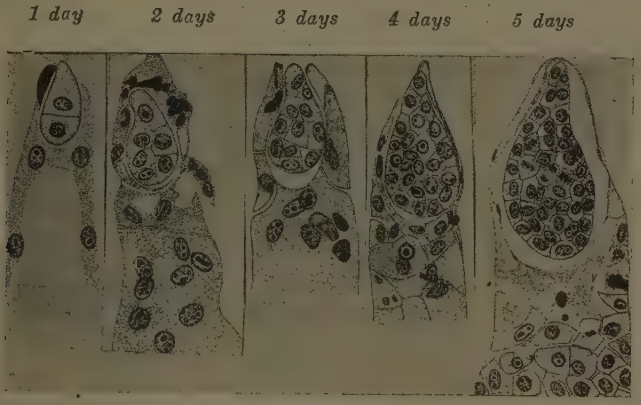

Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5.

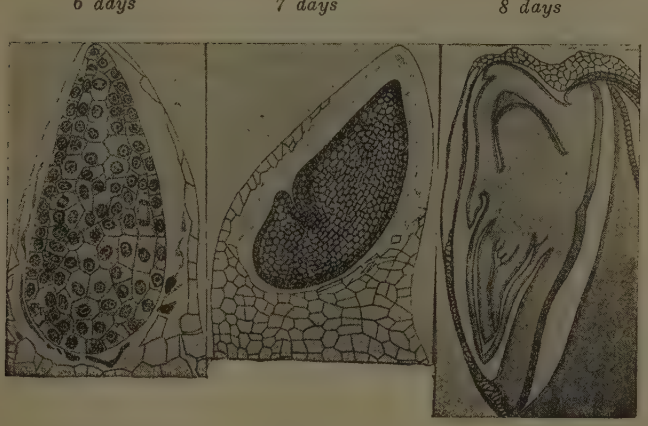

Fig. 6. Fig. 7. Fig. 8.

hybrid embryo and endosperm used to be arrested at early stages, and they died before normal development was completed; owing to this, seeds either were not formed at all, or proved poorly filled and unviable. These are the causes of the failure to cross various species of wheat with *Elymus*. Evidently these species are genetically so remote that crossing but on isolate occasions leads to embryo and endosperm formation and these, moreover, die at early stages.

In this paper I shall dwell in some detail on the results obtained from the study of the cross *Tr. Timopheevi*×*E. araliensis*, since similar results were

obtained by me for the cross *Tr. vulgare*×*E. dahuricus*, and in other combinations, as noted above, no development of either embryo or endosperm was found.

When *Tr. Timopheevi* is pollinated with its own pollen the development of the embryo and endosperm proceeds in the following manner (Figs. 1—8). One day following pollination a two-celled embryo and a few free nuclei of the endosperm are formed. After two days the number of nuclei and cells

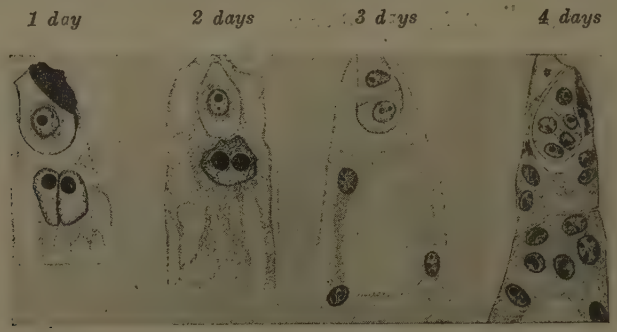

Fig. 9. Fig. 10. Fig. 11. Fig. 12.

Fig. 13. Fig. 14. Fig. 15. Fig. 16.

in the embryo increases to 6—8 and the endosperm becomes multinucleate. Upon 3 days the embryo becomes multicellular, the number of the endosperm nuclei further increases and cell-walls begin to form between the nuclei at the upper part of the embryosac. On the 4th day there is a further increase in the number of nuclei and cells in the embryo and endosperm. After 5 days, the embryo still increases and the whole of the endosperm consists of cells. On the 7th day the embryo becomes rather large and elongated. After 10 days differentiation of the embryo begins, there appears the growing cone of the stem and the cotyledon. Approximately on the 25—30th day following pollination the embryo and endosperm are fully formed. The embryo assumes the appearance represented in Fig. 8.

When *Tr. Timopheevi* is pollinated with pollen of *E. araliensis*, embryo- and endosperm formation takes place on extremely rare occasions; the course of events on such exceptional occasions is as follows (Figs. 9—16). A two-celled embryo and a few free nuclei of the endosperm are formed only 3 days following pollination. Several cells in the embryo and multinucleate

endosperm were found only on the 4th day. After 5 days there were observed multicellular embryo and the beginning of formation of cells in the endosperm. After 7 days there was found a somewhat larger embryo than on the 5th day, a greater number of cells were found in the endosperm. Owing to the arrest of growth, after 10 days both the embryo and the endosperm scarcely differed in size and cell-number from those of the 7th day.

Besides, cases were observed in this cross when no endosperm was formed at all owing to the failure of the polar nuclei to fuse and divide (Fig. 15).

I was unable to observe embryos or endosperm to develop further than shown in Fig. 16, since this is reached only in single cases, the majority of embryos and endosperms dying at the very first stages of development.

Upon comparison of the data obtained by me with those available in literature, I must state that the formation of an embryo and its death at early stages in intergeneric crosses had been previously observed in the crosses *Nicotiana paniculata*×*Petunia violacea*, *N. glauca*×*P. violacea*, *N. suaveolens*×*P. violacea* ([2]); this phenomenon was taken to account for the negative results obtained. The process of development of the embryo and endosperm in *Tr. Timopheevi* was not studied previously; neither was it studied in detail in any other species of hard wheat.

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GENETICS

EMBRYOGENESIS IN REMOTE HYBRIDIZATION IN THE GENUS *TARAXACUM*

By V. PODDUBNAJA-ARNOLDI

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Data on embryonic development in remote hybridization, on the causes and character of incrossability of species and genera, on sterility of hybrids etc. are very scarce, however, necessary for devising methods of combating these adverse phenomena. Work in this field seems to me, therefore, very desirable. While studying interspecific hybrids in the genus *Taraxacum* I have found them to be almost completely sterile, which was caused, on the one hand, by degeneration of pollen and of embryosacs prior to fertilization, and by degeneration of fertilized egg-cells and of embryo at various developmental stages, on the other. Data on the development of pollen and of embryosacs in hybrids obtained by me are contained in another paper of mine ([4]); those on fertilization and embryo development in these hybrids are reported here.

When *T. kok-saghyz* is pollinated by its own pollen at dry and hot wheather (at a mean temperature of 18—20° and 60-70 per cent of mean humidity), the processes of fertilization and embryo development proceed as follows (Fig. 1): half an hour after pollination double fertilization takes place, after 4 hours there occurs the first division of the endosperm nucleus; after 5 h. the first division of the egg-cell nucleus takes place; after 6 hours two-celled embryo and binucleate endosperm are formed; after 8 hours there are 4 cells in the embryo and 4 nuclei in the endosperm; after 24 hours there are a multicellular embryo and a multicellular endosperm: in 3 days cotyledons of the embryo are indicated; after 6 days the embryo is fully formed. The development of the embryo in other species of *Taraxacum* which were used for crossing (for example *T. multiscaposum*, *T. bessarabicum*, *T. serotinum*) was studied in lesser detail as compared to *T. kok-saghyz*, nevertheless, it was found to proceed in an analogous manner, if the conditions are similar. It should be remembered, however, that the rate of formation and development of the embryo in species of *Taraxacum*, like in other plants, varies in connexion with the changes in external conditions; it is slowed down and even completely arrested by unfavourable conditions. When *T. kok-saghyz* is pollinated with pollen of other *Taraxacum* species, for example of *T. multiscaposum*, the processes of fertilization and embryonic development are proceeding, mainly, in a manner similar to that in case of self-pollination, with the only difference that the proportion of fruit-setting is lower in the former case; this is due to the failure of every egg-cell to be fertilized when pollination is done by foreign pollen and also to the fact,

that not all of the fertilized egg-cells produce embryos. Data on the proportion of fruit setting in interspecific crosses in the genus *Taraxacum* are reported in a paper by V. Koroleva (²).

Normal development of the hybrid embryo seems to be intimately connected with a good crossability and with the ease of obtaining interspecific hybrids in this genus (when *Taraxacum* species are crossed which are sexually normal and possess equal chromosome numbers). On the contrary, when there is partial or complete incrossability of species or genera, one may observe both instances of complete or partial failure of the embryo to develop and cases of highly delayed development or of degeneration of the underdeveloped embryos, owing to which hybrids are either not formed at all or arise very rarely [Kostoff (³), Gollmick (¹)]. When *T. kok-saghyz* was pollinated with pollen of parthenogenetic species (*T. officinale*, *T. brevicornu-*

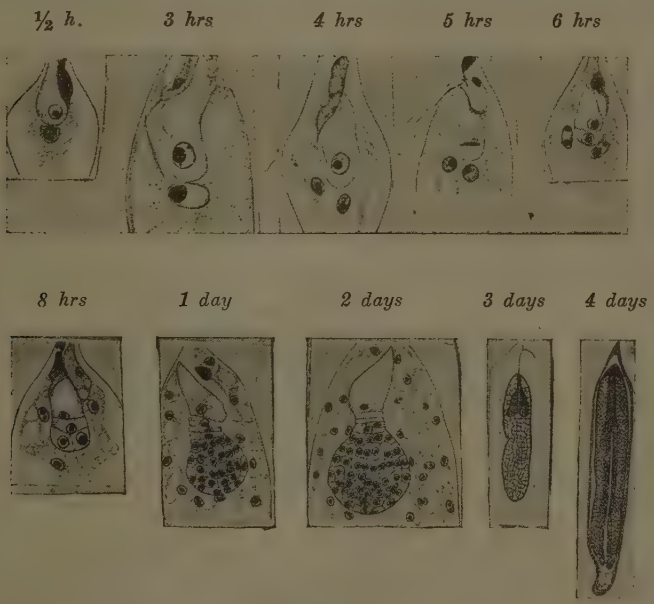

Fig. 1.

culatum, *T. hibernum*) not only did I fail to observe the formation of embryos or endosperm, but of fertilization, too; this was due to the fact that the pollen of the parthenogenetic species failed to germinate on the stigmas of *T. kok-saghyz* or of the other sexually normal *Taraxacum* species. This makes it clear why neither I nor V. Koroleva succeeded in obtaining hybrids from the pollination of *T. kok-saghyz* (and other sexually normal species as well) with pollen of parthenogenetically propagating species. As to the development of the embryo and of the endosperm in interspecific hybrids in the genus *Taraxacum*, it should be emphasized here that, owing to the high sterility of pollen and of embryo sacs, fertilization and embryo development take place very rarely in them, and in those cases when they do occur, the development of embryo usually proceeds very slowly or, not infrequently, ceases altogether, leading to degeneration of the underdeveloped embryos. This accounts for the extremely low proportion of fruit setting in the hybrids (from 2 to 3 per cent on the average). Nevertheless I have obtained further

generations from a number of hybrids, mainly through pollination of the hybrids with pollen of the one of the parents, namely of *T. kok-saghyz*, since the hybrids proved to be nearly self- and cross-sterile.

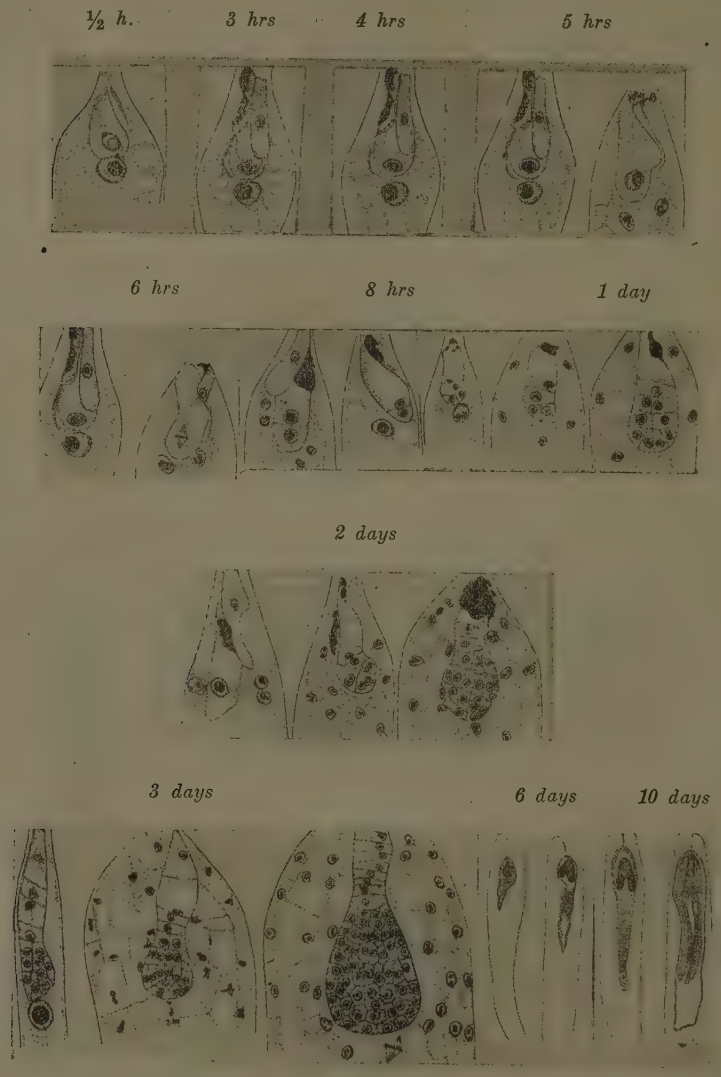

Fig. 2.

The processes of fertilization and embryo development in the hybrid *T. kok-saghyz*×*T. multiscaposum* when it is pollinated with pollen of *T. kok-saghyz*, were studied under conditions similar to those under which the crosses *T. kok-saghyz*×*T. kok-saghyz* and *T. kok-saghyz*× *T. multiscaposum* were studied. It has been found that the development of the embryo and of the endosperm proceeds here slower and with a lesser synchrony than in the

parental species, and that many embryos often remain underdeveloped and degenerate at early stages and that endosperm often degenerates or is not formed at all. The delayed development of both embryo and endosperm, rather frequent cases of their underdevelopment and degeneration expressed in a disturbance of the formation of wall partitions, in the cells and nuclei stopping to divide and their destruction—all these surely depend on hybrid nature rather than on the influence of the surrounding medium, since, ceteribus paribus, such phenomena used to be observed only in hybrids. When the hybrid *T. kok-saghyz*×*T. multiscaposum* was pollinated with pollen of *T. kok-saghyz* (Fig. 2) fertilization was found to occur $^1/_2$ hour following pollination. After 5 or 6 hrs on single occasions the first division of the endosperm nucleus and the first division of the egg-cell nucleus were observed, whereas the majority of the egg-cell nuclei and endosperm nuclei remained undivided. After 8 hours there were observed cases of formation of a 2-celled embryo and of 2—4-celled endosperm, whereas the majority of endosperm and egg-cell nuclei were still undivided. After 24 hours both 4-celled and multicellular embryos were found. Some of them appeared normal, others were underdeveloped for degenerating. Endosperm sometimes failed to develop. After from two to three days multicellular embryos and endosperms were observed in the majority of cases; some of them looked more or less normal, others degenerating. The formation of cotyledons was usually observed in the hybrid after 6 days and a fully formed embryo was found after 10 days only; moreover, only a small number of embryos reached the final stages of development, the majority died without having obtained full development.

Along with the ordinary double hybrids in the genus *Taraxacum* I have also obtained a triple hybrid. It was obtained from pollination of the hybrid *T. multiscaposum*×*T. kok-saghyz* by the third species, *T. serotinum*. The triple hybrid exhibited great external similarity to *T. serotinum* and possessed large inflorescences which attained 35—40 mm in diameter.

The development of the embryo in the formation of the triple hybrid proceeded slowly and degeneration of the embryo and of the endosperm was often observed at earlier or later stages of development. However, some of the embryos reached full development owing to which fact I succeeded in obtaining a small amount of normally filled seeds which further produced adult plants.

The study of the development of pollen and of embryosacs in triple hybrids has shown that division proceeds as normally as in parental species. As a result of a regular conjugation of the chromosomes, 8 normal bivalents are formed in triple hybrid. Tetrads of the micro- and macrospores have their usual appearance; nevertheless, their mass-degeneration begins most commonly during the 1st or 2nd divisions in the pollen and embryosac. A certain amount of normal 3-nucleate pollen and of normal 8-nucleate embryosacs was nevertheless found in the triple hybrid. Sterility in the triple hybrids was so great, that I was unable to obtain seeds from them. Yet, I have established that triple hybrids which are distinguished by a sterility still greater than that in the double ones, showed no ability to propagate parthenogenetically like the double hybrids.

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GENETICS

EFFECT OF TEMPERATURE BELOW 0° UPON THE PROCESS OF MUTATION AND SOME CONSIDERATIONS ON THE CAUSES OF SPONTANEOUS MUTATION

By JUL. KERKIS

(Communicated by N. I. Vavilov, Member of the Academy, 8. V. 1939)

After the discovery of the possibility of artificial production of mutations by means of short-wave radiation a new way was opened to genetics in the field of inquiry into the nature of the gene. The study of the principles of the transmutational effect of the short-wave radiation and of other physico-chemical agents has played an outstanding part in the development of our ideas on the nature of the genes and of the mutational changes. The study of the mutational process artificially induced is, however, interesting not merely as one of the methods of approach to the nature of the gene but, moreover, it is of importance for the interpretation of the principles of the spontaneous mutation process and for discovering its causes.

Up to the recent time geneticists were to such an extent absorbed in the application of short-wave rays to the production of mutations that in all generalizations bearing on the rôle of mutations in evolution, genetics proceeds from the known principles of the «X-ray mutation process». Such an extrapolation is not obviously lawful ([13], [18]), inasmuch as short-wave radiation is a factor of very slight importance under natural conditions ([1], [3], [4], [8], [9], [12], [17], [20]). These considerations emphasize the desirability of the study of transmutating effect of such agents which are most commonly operating under natural conditions.

One of these agents under the action of which proceeds the development of all the living beings, is the temperature regimen of the medium. Attempts to produce hereditary changes by temperature influence were already made in the earliest days of the science of heredity. It was discovered prior to the possibility of producing artificial mutations with the aid of X-rays that the rate of occurrence of mutations increases with the rise of temperature. It was natural, therefore, that when an exact quantitative method of registration of mutations became available, the search of a factor responsible for spontaneous mutations—the only primary source of the «raw material» out of which new forms are created by selection—was primarily concerned with temperature.

The number of experimental studies devoted to the transmutating effect of a temperature above 0°, is rather large. If one excludes the highly peculiar results obtained by Goldschmidt ([5]) and Jollos [([10],[11]) and earlier papers] which failed to be corroborated by later workers who tried to check the results of the above authors, the outcome of the studies bearing on this point may be summarized as follows. The action of an increased tempe-

rature administered in the form of more or less short «shocks» at definite stages of development or regularly in the course of the development of the organism, causes an insignificant increase in the mutation rate which cannot be compared with the analogous effect caused by short-wave radiation. Taking into account the data of various writers, the temperature coefficient of the transmutating effect (Q_{10}) is found to be from 2.5 to 5.0, i. e. an increase by 10° is connected with the mutation rate increasing from 2.5 to 5.0 times. The frequency of mutation is a very low one, but rarely exceeding 1 per cent.

Müller ([15]) and following him others ([14]) have concluded from the above data that the dependence of the mutation process on temperature follows the law discovered by Vant Hoff for chemical reactions. Many authors were thus inclined to regard the mutation process as a chemical reaction and the temperature as a factor accelerating it. We already had an opportunity ([14]) to point out that the various external agents which cause mutation should not be regarded as merely accelerating the course of the mutation process. This equally applies to temperature, in spite of the fact that the quantitative side of the phenomena observed in the temperature action seems at the first sight to be subordinated to the same principles as chemical reactions.

To approach the solution of the question as to the correctness of such an idea of the nature of the action of temperature we have arranged an extensive series of experiments on the transmutating effect of negative temperature, since already the results by Gottschewski ([6],[7]) and Birkina ([2]) gave us ground to believe that the similarity between the dependence on temperature in mutations and chemical reactions is probably nothing but a matter of chance. The scheme of the experiments was as follows: adult males of *Drosophila melanogaster* homozygous for the genes *brown* and *ebony* (located in the II and III chromosomes, respectively), were subjected to the influence of a temperature of—5.5—6.0° C during 1½—2 hours by immersing the vial with the flies into a refrigerating mixture. The temperature of the mixture was checked during the whole time of the experiment. Altogether 34 000 males were subjected to treatment, 300—400 flies at a time. Out of the whole number of males frozen only 53 survived. The surviving males were immediately crossed with virgin *BCl* females. The F_1 females heterozygous for the treated *X*-chromosome were individually crossed with males *y fa vf* ♂ 49 in order to record sex-linked lethals. The F_1 males were backcrossed with homozygous *bwe* females for recording translocations between *Y*, I, II III chromosomes. All cases where there might be suspected a lethal or a translocation were checked in one additional generation, irrespective of the number of flies in the given culture.

Among 917 sex chromosomes which were subjected to the cold treatment described above, the study revealed 13 lethals, which constitutes 1.42 per cent. No translocations were found among the 1254 cultures studied. In the control among 1934 cultures 5 lethal mutations were found which constitutes 0.26 per cent. No translocations were found in the control. The difference between the number of lethals obtained in the experiment and that in the control is 1.16 ± 0.318, i. e. is statistically significant.

The proportion of mutations obtained in our experiments is still greater than in other investigations devoted to the study of the transmutating effect of low temperature ([2], [6], [7], [21], [22], [23]). This result makes us believe that the agreement between the character of the action of positive temperatures upon the mutation process and the principles described by Vant Hoff for chemical reactions is probably a matter of chance. Mutations which represent changes in some complex organic structure called the gene may arise as a result of

any disturbance in the biochemical balance of the cell or chromosomes caused by any physiological or physico-chemical factor which is external to this structure. On the basis of a study of the chromosome mutation frequency in ageing seeds M. Navashin ([24]) came to similar conclusions. Therefore, it appears to us hopeless to look for any specific agent responsible for the spontaneous mutation process. The cause of mutations is the same as that of any change in any material, viz., interaction between the genic substance and the surrounding medium, the latter being considered in the widest sense. All the immense variety of forms of interaction between the organism and the surroundings and the intracellular metabolism connected with it (in particular, changes in pH) are responsible for the mutation process going on in this organism. The short-wave radiation assumes an isolated position owing to its specific ability of causing strictly local changes in molecular structures; as shown by many experiments, the rôle of this factor in the spontaneous mutation process is a very limited one.

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CYTOLOGY

CYTOLOGICAL STUDY OF *SOLANUM MILLANII* BUK. et LECHN.

By E. V. IVANOVSKAJA

(Communicated by N. I. Vavilov, Member of the Academy, 2. VI. 1939.)

It was of interest to find out the genetic composition of the wild frost resistant potato from Argentine, *Solanum Millanii* Buk. et Lechn. (1). The chromosome number $2n=36$ was determined by Rybin and verified by us (Fig. 1). Shepeleva has determined $2n=24$ from the I metaphase (the same number was previously found by S. Horovitz). Cases of formation of 12 elements at the I metaphase observed by Shepeleva (Fig. 2 made from the drawing by Shepeleva from acetocarmine preparation) and by us made one suggest the presence of three related genomes forming 12 trivalents.

Fig. 1. Somatic plate, × 3200.

Fig. 2. Metaphase of the I division with 12 elements (from a drawing by Shepeleva).

Bukassov had advanced the assumption that the most probable relative of *S. Millanii* might have been a species closely related to the diploid *S. chacoense* Bitt, $2n=24$, which is taxonomically related to *S. Millanii*. It appeared possible, therefore, that *S. Millanii* is a triploid of *S. chacoense* or of a closely related species.

In order to clear up this question meiosis in anthers of *S. Millanii* was studied; anthers were fixed in Navashin's fluid after examination in acetocarmin. The metaphase (Fig. 3) presented difficulties for counts, the elements being not regularly arranged in one level.

Number of elements at the equator of the metaphase of the I division

Number of elements	11	12	13	14	15	16	17	18
Number of cases	1	4	10	14	11	7	2	1
Per cent	2	8	20	28	22	17	4	2

Plates with 14 elements were those most frequently met. Theoretically these plates showing no lagging elements should contain 8 trivalents (24 chromosomes) and 6 bivalents (12 chromosomes); other variants should either contain univalents, or the number of elements should be other than 14.

Number of elements out of the equator of the metaphase of the I division

Number of elements	0	1	2	3	4	5	6
Number of cases	41	51	45	30	15	2	1
Per cent	22	28	24	16	8,5	1	0.5

Sixty-eight per cent of the metaphases contained 1—3 elements of varying valency outside the plate. This number is the smallest as compared to the data by Vilmorin (2) on *S. Commersonii* $2n = 36$ (4—8) and to those of Oppenheimer (3) on triploid hybrid *S. chacoense* × *S. tuberosum* (up to 12). Olah (4) has established the homology of all the 4 genomes constituting the tetraploid hybrid *S. chacoense* × *S. tuberosum*; two of its genomes represent the diploid set of *S. chacoense* and two—the hyploid set of *S. tuberosum*.

It was difficult to determine the valency of all the elements in metaphases owing to their irregular arrangement; however, one usually could observe 3—4 trivalents per plate, rarely and without full confidence 5 of them. The trivalents observed showed equal configuration which should point to an equal degree of attachment among them. Single quadrivalents were met with.

Fig. 3. Metaphase of the I division with 12 elements and one element extruded into the cytoplasm, × 3200.

Fig. 4. Chromatin bridge, fragment and division of an univalent at the anaphase of the I division, × 3200.

Fig. 5. Metaphase of the II division, there are 18 chromosomes in each plate, × 3200.

At the anaphase of the I division a certain number (about 3 per cent) of chromatin bridges was observed. A bridge with a fragment is represented in Fig. 4. There are less elements extruded into the cytoplasm at the interphase than at the metaphases of I division. The division of an univalent was observed twice (Fig. 4); once the sum of the chromosome numbers of the two plates of the II division proved equal to 38. An intimate association of individual chromosomes could be sometimes observed at II metaphase. Once there were observed 14 extruded elements at the telophase of the I division.

The metaphase of the II division (Fig. 5) has usually an appearance of equal girdles; the diverging toward the poles is in the majority of cases rather regular.

Number of elements at the equator of the metaphases of the II division

Number of elements . .	12	13	14	15	16	17	18	19	20	21	22
Number of cases	2	2	1	13	16	30	23	24	9	5	1
Per cent	1.6	1.6	0.8	10.4	12.8	24	18.4	19.2	7.2	4	0.8

Compared with the metaphase of the I division the maximum appears to be shifted here to the right; as should be expected for multivalent formation, 74 per cent of the I metaphase counted contained from 16 to 19 elements.

Aside from tetrads, a considerable number of pentads and hexads were observed. The fifth and the sixth cell were considerably smaller and contained no nuclei. In some cases the appearance of chromatin in 1 or 2 cells of a tetrad suggested degeneration. A certain number of meta-anaphases could be observed, but not a single plate with somatic chromosome number

was found. No dyads were observed, probably owing to the scarcity of material examined.

The presence at the metaphase of the I divistion of 12 elements makes one suppose that 12 trivalents were formed in this case, i. e. that, though rarely, complete conjugation of the three genomes was effected here. In the remaining cases trivalents were in minority; consequently, conjugation was a partial one. This may depend either on the decrease in length of the conjugating trivalents, or on the fact that homology among the groups of three is not strong enough to overcome the difficulties encountered.

The diploid *S. chacoense* closely related to *S. Millanii* has the same area—Paraguay and Argentine; its external appearance approaches to that of *S. Millanii* (1), too. The two have stellate corolla, white flowers [*S. chacoense* has sometimes bluish ones—Fedde (6)]. Leaves are large with large lobes, four-paired; there is usually one pair of lobes. The width of the apical lobe greatly exceeds that of the paired lobes. Pedicles of mature flowers are bold or slightly pubescent. Anthers about 6 mm with a distinct heart-shaped hollow [description of *S. chacoense* is adopted from the key by Lekhnovich (7)]. However, there are differences between these species, too.

Several writers point to the formation of diploid gametes in *S. chacoense*. In his paper already referred to (3) Oppenheimer described a 48-chromosome hybrid *S. chacoense* × *S. tuberosum* obtained from a diploid gamete of *S. chacoense*. Propach (5) has studied further hybrids of the same constitution and arrived at a conclusion on the participation in them of maternal diploid gametes.

These data support the supposition of *S. Millanii* having originated from a diploid female gamete of *S. chacoense* fertilized by a haploid gamete of some of the closely related diploids. Chromatin bridges and varying configurations in the trivalents point to some structural differences existing among these genomes.

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PLANT PHYSIOLOGY

ROOTING OF WOODY CUTTINGS AS DEPENDENT UPON PHOTOPERIODIC CONDITION

By B. S. MOSHKOV and I. E. KOCHERZHENKO

(Communicated by N. I. Vavilov, Member of the Academy, 19.V. 1939)

Photoperiodism invariably suggests the idea of a plant passing from the growth to the reproduction phase, i. e. to seed propagation. However, the vegetation propagation of plants is no less strongly dependent upon the photoperiodic conditions of their growth. As early as in first publications by Garner and Allard there was pointed out the relation between tuber-formation and photoperiods in such species of plants as the Jerusalem artichoke and potato. Similar information is available on the propagation of plants by means of bulbs, tendrils and root stocks. The rooting response of woody cuttings to photoperiodic conditions was first observed in 1930 by Moshkov on *Salix undulata* which in the preceding year had been treated with various photoperiods. The cuttings which had been taken from plants given long days in the preceding year stroke roots under short day conditions much better than did those taken from the plants which had received 10-hour days.

A special experiment was arranged in the following year with the aim to find out the cause of the different behaviour of the seedlings and this was run with three species of the plant mentioned. The results are summarized in Table 1.

Table 1

Species and origin of parent plants	Photoperiodic treatment of parent plant	Long day (18 hours)		Short day (10 hours)	
		% of rooting	Increment	% of rooting	Increment
Salix undulata Pushkin, near Leningrad	long day 18 hrs.	100	39	100	7.8
	short day 10 hrs.	0	0	0	0
Salix Pierotti Japan	long day 18 hrs.	42	16	70	6.4
	short day 10 hrs.	75	28	90	6.3
Salix Babylonica Sukhumi	long day 18 hrs.	60	31	55	13.5
	short day 14 hrs.	95	37	65	19.3
	» » 10 hrs.	70	53	35	12.5

From the table it is obvious that *Salix undulata* was the only species whose cuttings had rooted without a single exception whether on short or long daylength. Among the other two species *Salix Pierotti* showed bet-

ter rooting with short days while for *Salix Babylonica* long day conditions proved more favourable. The cuttings of *S. undulata* from long day plants gave full ratio of rooting. The cuttings of the same species taken from short day plants failed to root in the year of planting yet they did not perish. The cuttings of *Salix Pierotti* rooted better if their parent plant had been given short and not long days. In *Salix Babylonica* long day treatment of the parent plant was conducive to better rooting compared to the control

Fig. 1. Rooting of cuttings of *Salix undulata* taken from short-day (left) and long-day (right) plants at different dates: July 25 (above), August 1 (in the middle) and August 5 (below).

on the short day treatment. If the photoperiodic conditions under which the cuttings had grown and those under which they had to strike roots are considered together, the unlike behaviour of the species tested becomes also apparent. In *S. undulata* the highest proportion of rooting was obtained by the long day cuttings when they had to root under long day conditions. At the other end of the scale is *S. Pierotti* in which the best results were obtained with short days during growing and rooting. Among *S. Babylonica* those cuttings gave the highest proportion of rooting which had been taken from 14-hour day plants and treated with long days. It will

be obvious that the regeneration processes which work for the creation of a new individual from the cutting planted proceed differently on different daylengths, and depend not only on those photoperiodic conditions under which they have to take place, but also, and even to a higher extent, on those under which the parent plant has been growing.

The factors underlying the established regularities were revealed in the years 1934—1935. Most of the species, especially the northern ones, were found to root better on continuous illumination. Thus, the shoots from *S. undulata* grown on 10-hour days from spring onwards and cut July 25 could be induced to rooting only by continuous days. Certain differences were observed thereby in the formation of roots between the cuttings from the short day plants and those from the long day plants. While in the former the roots were concentrated about the lower cut only, they had in the latter (controls) overgrown nearly a half or a third of the length of the cutting. Furthermore, both the roots and shoots were more vigorously developed in the cuttings from the short day plants than in the controls. This was probably because the former were more richly stored with plastic substances. However, the cuttings which had completed their growth on a short day plant could not be induced to make growth again even by a continuous illumination if the latter was given to them not at once, but 5—10 days later, and the day had continued short during this time (Fig. 1).

When the cuttings were taken every 5—10 days from the northern species of willow and black currant growing on natural daylength (controls) and on daylength ranging within 8—16 hours, it was observed that those from the short day plants were the first to root. Rooting of summer cuttings fell within the time when the shoots started liquefaction, and it was the base at which then stroke roots readily while the top rooted poorly. Complete rooting of all parts of a shoot was observed when induced toward the end of the growing season. Those woody species which respond to photoperiods by changing their annual growth, have the latter soon completed on a short daylength. It is therefore only natural that the shoots grown under these conditions start rooting earlier compared to the shoots from the long day plants. This relation holds true whether the species concerned is of a northern or a southern origin, but only for a certain time of the year. Experiments made at later dates show that the cuttings from northern parts grown on a short daylength will not root at all, whereas those from the southern plants grown under the same conditions are able to root throughout the year. The failure of the shoots to root may be accounted for by their entering the dormant state which is usually more deep in the northern species. On the other hand, the short photoperiods are known as a strong factor inducing dormancy.

Salix viminalis and *Salix undulata* which are much akin with regard to their geographic origin but have different dormant periods, produce shoots which are not alike in their ability to strike roots by the end of summer or in autumn (Table 2). The shoots from control plants of *S. viminalis* root in full number in 7—10 days from the end of July and do not lose the rooting ability later. This points to the fact that this species is not deeply affected with dormancy. The shoots of *S. undulata* grown under the same conditions refuse to root early in October albeit for a short time. If the plants of *S. undulata* be taken from the short day to the hot-house early in August, their shoots will not root at their usual dates. After having passed into dormant condition the shoots are unable to root until dormancy is broken by lower temperatures. If grown on short daylengths the species show still more striking differences according to their varying degrees of affection with dormancy (Table 2). Under these conditions the shoots from

Table 2

Date of cutting	Rooting on continuous illumination							
	Salix viminalis				*Salix undulata*			
	Natural day		9-hour day		Natural day		9-hour day	
	in %	in days	in %	in days	in %	in days	in %	in days
25.VII	100	7	100	9—14	100	9	100	9—14
1.VIII	100	7	100	7—16	100	6 — 7	50	17—31
5.VIII	100	9	80	9—23	100	7	0	—
10.VIII	100	8	78	6—40	100	7	0	—
12.VIII	100	6	55	9—30	100	6— 7	0	—
1.IX	100	9	0	—	100	9	0	—
5.IX	100	8—10	73	10—50	100	9—10	0	—
10.IX	100	7—10	75	10—40	100	10	0	—
20.IX	100	7— 8	82	10—30	100	18—20	36.4	30—39
25.IX	100	7— 9	—	—	100	10—20	—	—
1.X	100	5— 8	100	15—25	40	12—19	100	11—22
5.X	100	5— 7	100	12—23	40	9—20	100	12—22
11.X	100	7—10	100	15—21	0	—	100	11—19
15.X	100	5—11	100	9	46	13—40	100	9—10
21.X	100	10	100	10	60	21—42	100	10—19
25.X	100	9	100	9—11	100	17—40	100	11—16
1.XI	100	9—11	100	9—12	100	12—18	100	9—16
5.XI	100	9	100	8—11	100	12—23	100	12

S. viminalis retain almost their whole power of rooting, while the shoots from *S. undulata* refuse to root for a long time (from early in August till the end of September). The condition which suggests itself when we are making such experiments at that time is that these species require quite different photoperiods for preparation of their shoots to rooting. However, what each of them requires in reality for successful rooting of their cuttings in summer, is such a number of short days which will make the annual growth complete.

Conclusions

The relation between the rooting power of shoots and the photoperiodic conditions experienced by the parent plant as well as the differences between the species in this character are essentially determined by the processes involved in the growth of the plant and its transition to dormancy. In northern latitudes some of the species, especially those of southern origin, produce shoots that root poorly if at all, because they fail to complete growth under these conditions and reach the physiological state indispensable for rooting. By growing such species on a short daylength we can greatly enhance the rooting ability of their shoots. The photoperidic conditions are also a very important factor in providing the shoots which have to root in summer with plastic substances. In general, the best plan for preparing the shoots to successful rooting is to grow the parent plant on such daylength which is optimal for its life activity. This applies to both deciduous and evergreen species (citrus plants). At the time when root-formation is to take place it is better induced in most of the species by continuous illumination.

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PLANT PHYSIOLOGY

AIR CONDITIONING APPARATUS FOR DRY WIND TESTING OF PLANTS

By A. E. VOTSCHAL

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Every investigator engaged in the study of physiological problems connected with atmospheric drought and dry winds has certainly realized the necessity of constructing an apparatus which would make it possible carefully to control the conditions of a microclimate created according to the experimental plan and to keep away the influence of the weather at any time. The plant breeder is also in need of such a device while testing farm crop varieties for their drought or dry wind resistance.

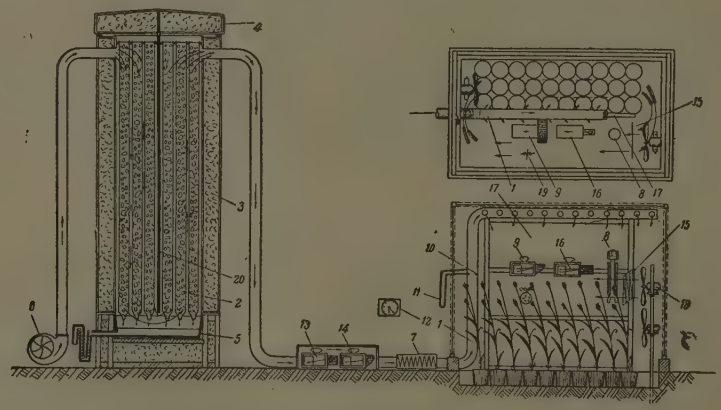

Fig. 1.

According to the information available in literature only a few attempts have been made along this line. Several different devices for controlling the air humidity or creating dry wind conditions are reported in the works of Krasnoselskaja-Maximova (1931), Krasnoselskaja-Maximova and Condo (1933), Shirley (1934), Aamodt (1935), Mitchell (1936), Grandfield (1937) and others. These apparatus are either too small (no more than two specimens can be tested simultaneously) or their drawback is that the experiment is strongly dependent upon the content of water vapour in the outside air, which is admitted into the chamber after its relative humidity has been reduced by heating. The object of this author's efforts was therefore

a contrivance which would perfectly meet its intended purpose. This was achieved at the physiological laboratory of the Institute of Plant Industry at Pushkin. The apparatus constructed has been working without a hitch since 1937. It consists as shown in the Fig. 1 of a refrigerator (type A. B. 5) used for chilling and, eo ipso, drying the outside air, and of a glass chamber (type A. B. 2) in which plant material under test is placed. The desired conditions of air humidity, temperature and wind velocity are automatically controlled in the chamber. A feature characteristic of this apparatus is that the different factors, as humidity, temperature and velocity of the air, are controlled quite independently of one another. It is only owing to this complete separation of controlling processes that we are able to set up

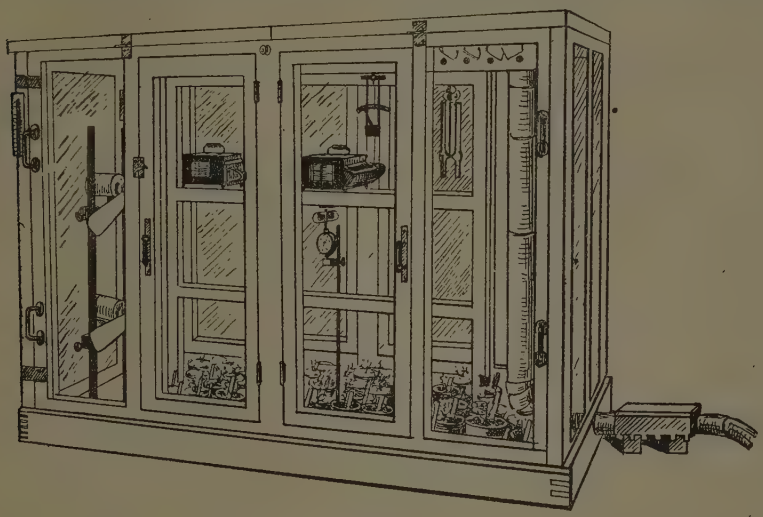

Fig. 2.

the required combination of the above factors in the chamber. Moreover, a periodical and not a continuous admission of dry air without changing the wind velocity in the chamber goes to reduce the expenditure of ice considerably (300—450 kg in 24 hours).

I. Control of Humidity

The chamber for experimental plants consists of frames furnished with one layer of glass. For sake of easier handling it is designed to be mounted on the place of operation. The useful flow area is 2 m^2, the volume 5 m^3. The air cooled and dryed in a refrigerator is piped (1) into the chamber, after it has been adjusted to the desired temperature by means of an electrical heater (7). When the chamber is fully loaded with experimental plants (62 four-inch pots), the air humidity starts rising fast, coming to 70—80% in a short period of time. Experiments have shown that for the humid air to be displaced and a low relative humidity (15—10% and lower) characteristic of a dry wind to be established in the chamber, considerable quantities of dry air (250—400 and more cm^3 per hour) are required. Such amounts of dry air could by no means be obtained if we were to resort to the methods which the other investigators used for expelling the water vapour ($CaCl_2$ and H_2SO_4). Neither could the low degrees of humidity be adjusted

by merely heating the air. The method of this apparatus is to drive out water vapour by condensing it on a strongly cooled surface of several narrow (0.1 m) and long (3 m) canva bags (2) filled with ice-salt mixture. These bags, as shown in Fig. 1, hang in the cylindrical refrigerator case (3) which is insulated as is the lid with which it is tightly closed (4).

A partition (20) dividing this cylinder into two equal parts doubles the length of the way which the air has to make between the bags with ice-salt mixture (as indicated by arrows). The total surface of the bags being equal to 20 cm^2, it is not a difficult matter to cool the required amount of air, with absolute humidity 1.8—1.4 mm, to as low a temperature as 12—15°. The brine trickling down from the bags is collected below (5) and conveyed off by a siphon. The air, dried and heated, reaches the chamber to mix with the humid air and reduce its relative humidity sharply.

After the desired degree of humidity has been indicated by Assman's psychrometer (8), a moisture control device (type A. B. 3) is put into operation, which maintains the established conditions of humidity by switching in and off an exhauster (6). The mechanism for controlling the moisture is a modified type of Rishar's hygrograph. The recording hand of the hygrograph served here as a sliding contact. The second contact (a magnetized needle with a platinum plate) is fastened to a small lever set on the axis of the recording hand. The lever with the second contact has a special sprig touching the surface of the hygrograph drum. A profile-curve is placed on the drum and has to guide the change in humidity during the experiment. By its means the run of decreasing humidity can be traced in advance. In the pipe conveying the air to the chamber diaphragm (10) is placed which is furnished with a differential manometer (11) for determining the velocity of the air forced into the chamber. A special counter (12) included into the chain of the moisture controlling device records the duration of exhauster's work (6). A hygrograph (13) and a thermograph (14) within the pipe recorded the change in the humidity of the dry air conveyed to the chamber, their indications being checked from time to time by Assman's psychrometer. The effect of the combined work of the moisture controlling mechanism (9) and the exhauster (6) is to establich and maintain the required air humidity with an error ranging between +0.5—1%. The water evacuated by the plants (transpiration), provided the soil evaporation be excluded, causes the humidity of the dry air admitted to the chamber to go up to a given value. Since the amount of air admitted and its humidity are known, we may find out the total transpiration of experimental plants with a probable error of 5%. Recording at regular intervals the amount of dry air admitted into the chamber, we can draw an integral curve of the transpiration process for all the plants under test. This curve is of particular interest if the experiment is being conducted on a homogeneous material.

II. Control of Temperature

For keeping the required temperature in the chamber there is installed in it an electrical air heater (15) located in front of one of the four fans. A thermoregulator (type A. B. 3) (16), the construction and the operation of which are quite identical with those of the moisture controlling device described above, makes the temperature follow the run of the curve drawn in advance, as it was the case in controlling humidity. To obviate overheating of the chamber on sunny hot days only a part of the sections of the heater is then switched in (7) and the temperature of the dry air coming in is 5, 10 or 15° below that in the chamber. But even in such critical moments the fluctuations in the air temperature in the chamber never exceed 1—2° C.

III. Control of Air Velocity

For obtaining a uniform current of air over the plants (wind) there is placed in the chamber a vertical glass partition (17) dividing the chamber into two parts. Two motors (18) furnished with propellers are installed in each part. The motors are placed on two shafts driven into the ground and can be transferred to different heights according to the height of the plants tested. The action of the motors creates in the chamber a circular current of air, the maximum velocity of which, as determined by means of an anemometer (19), amounts to 4.6 m per sec. From what has been reported here we can see how the idea of an independent control of the three various factors—temperature, humidity and wind velocity—has been brought into fact in this contrivance. The operation of the propeller motor group may be stopped by including a rheostat to obtain nearly motionless air of desirable temperature and humidity. In the summer of 1937 and 1938 several tests with wheats, leguminous plants, flaxes and buckwheats were conducted in this apparatus.

With the chamber loaded completely (in the tests with wheats we had about 130 plants) we succeeded in obtaining and long keeping a relative air humidity equal to 10—12% (in some cases the humidity of the air fell to 6%) at 30—40° C according to the scheme designed in advance. The apparatus worked automatically all the 24 hours round quite independently of the outside conditions.

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PLANT PHYSIOLOGY

COMBINED EFFECT OF COLCHICINE AND HETEROAUXINE UPON SEEDLINGS OF CAMPHOR-YIELDING BASIL

By V. GLOTOV

(Communicated by A. A. Richter, Member of the Academy, 5. VI. 1939)

The aim of the present experiment was to increase the viability of plants treated with colchicine. The death among young plants of camphor-yielding basil after their seeds had been treated with colchicine is known to amount mostly to 100 per cent, in the most favourable cases 80—90 per cent at low concentrations (0.0015 per cent and below). However, cytological studies have shown that extreme dilution of colchicine, although increasing the proportion of surviving plants, at the same time lowers its efficiency with regard to production of tetraploids. When low concentrations were applied, no entirely tetraploid forms were found, but merely single tetraploid cells or, at the best, groups of cells. On the contrary, when strong concentrations were used although very few plants survived, some of them were tetraploid throughout. In 1938, prior to the use of heteroauxine we were restricted in our possibilities by the lethal effect of colchicine; with the use of the growth hormone we expected to broaden the scope of our studies. One could hope that beyond these boundaries there were more favourable conditions. Therefore, it appeared of importance to obtain plants treated with a lethal dosage of colchicine, first, in order to check the above stated, and, secondly, for increasing the production of plants altered by the experiment. Observations have shown that the death of experimental plants was due to an extremely strong inhibition of the development of roots and root-hairs. Young seedlings already weakened by the effect of colchicine remained during a long time (up to 100 days) at the cotyledon stage and easily became victims of parasites (chiefly bacteria), and died. To avoid this one could logically think of two ways: the first one was to rear seedlings under strictly aseptic conditions in water or sand culture with artificial mineral nutrition. However, this way was inaccessible to us owing to the absence of necessary conditions. The other way was the use of substances stimulating root-growth, of growth-hormones. The most suitable for this purpose proved to be the heteroauxine—β-indol-acetic acide. This possibility was a quite real and, as shown by experience, a most valuable one.

In 1939 our cytological laboratory has arranged a methodical experiment in order to find out the necessary duration of the heteroauxine treatment and the concentrations of this substance when applied to seedlings which had been previously treated with colchicine. The concentrations of colchicine applied were as follows: 0.0063 per cent and 0.0015 per cent

Concentration of heteroauxine	1 : 1000						1 : 2000						1 : 4000						Total and average
Duration of treatment with the heteroauxine	12 hours	1 day	2 days	3 days	4 days	5 days	12 hours	1 day	2 days	3 days	4 days	5 days	12 hours	1 day	2 days	3 days	4 days	5 days	
Colchicine — 0.0063%																			
Number of plants planted	15	13	13	13	13	13	15	13	13	13	13	13	15	13	13	13	13	13	240
Left on the 20.IV. 1939	2	1	2	6	5	5	6	7	5	8	8	3	6	8	1	4	4	9	90
Per cent of dead plants	85.6	92.3	84.6	53.8	61.6	61.6	60.0	46.1	61.6	38.4	38.4	76.9	60.0	38.4	92.3	70.0	70.0	30.8	62.5
From them possessing true leaves	—	—	—	—	1	—	1	—	—	—	1	1	1	—	—	—	—	3	8
Per cent	—	—	—	—	7.7	—	6.7	—	—	—	7.7	7.7	6.7	—	—	—	—	23.1	3.3
Colchicine — 0.0015%																			
Number of plants planted	15	14	13	14	13	14	15	14	14	14	14	14	15	14	14	14	14	14	253
Left on the 20.IV. 1939	10	7	5	6	8	2	11	13	13	14	11	7	8	4	3	14	11	12	159
Per cent of dead plants	33.3	50.0	61.6	57.1	38.4	85.7	26.6	7.1	7.1	0.0	21.4	50.0	46.6	71.4	78.6	0.0	21.4	14.3	37.1
From them possessing true leaves	6	2	2	4	2	1	6	7	4	10	6	3	4	2	3	12	9	9	92
Per cent	40.0	14.3	15.4	28.5	15.4	7.1	40.0	50.0	28.5	71.5	42.8	21.4	26.6	15.4	21.4	85.6	64.3	64.3	36.3

which proved to be lethal in the control experiment of 1939; the concentrations of heteroauxine were 1 : 1000, 1 : 2000 and 1 : 4000, the duration of the treatment being 12 hours, 1—2—3—4 and 5 days.

Seeds were first germinated in the above-mentioned solutions of colchicine and after 6 days washed in water and treated with heteroauxine of various concentrations and for various terms. The heteroauxine treatment was done as follows: sand previously treated with strong heat was put into Petri dishes and moistened with a heteroauxine solution of the desired concentration. Young seedlings at the cotyledon stage were put into sand for various terms. Then, after washing, they were planted into flower-vases. The experiment was started on 26 of March, 1939.

The results of the experiment may be seen from the table.

Twenty control plants were planted; on the 20 May there remained 19 of them, all with true leaves. Thus, 5 per cent of plants died and out of the 95 per cent plants which survived all had true leaves.

It should be noted that the formation of true leaves in the camphor-yielding basil always guarantees further development of the plants under the green-house conditions. The death occurs mainly at the cotyledon stage.

From the above table one may see that the heteroauxine treatment of the seedlings previously treated with colchicine was highly effective. In those portions where 100 per cent of plants died after treatment with 0.0063 and 0.0015 per cent colchicine, 85.6 per cent of plants survived upon additional heteroauxine treatment.

All the plants which survived thanks to heteroauxine treatment showed strongly expressed morhological changes—thickened and intensely coloured leaves of modified form and a strong impediment of growth and development, i. e., characters which may serve to judge of the chromosome number. Further development and cytological analysis would supply concrete data on the subject.

The best dosage of heteroauxine for camphor-yielding basil treated with a 0.0015 per cent solution of colchicine thus proved to be the concentration 1 : 4000 with a duration of treatment equal to 3 days; it resulted in the production of 85.6 per cent of plants with true leaves. In case of the 0.0063 per cent colchicine solution the same concentration proved to be best, while the duration of the treatment had to be 5 days; it gave 23.1 per cent of plants with true leaves.

The positive effect of heteroauxine considerably increases the effectiveness of colchicine with regard to the production of tetraploid forms. It was pointed out above that the number of tetraploids obtained increases along with the increase in colchicine concentration. Now with the aid of heteroauxine we shall be able to surpass the limits of the lethal concentration and to check this regularity established with lower concentrations.

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PLANT PHYSIOLOGY

ON THE PHYSIOLOGICAL CONDITIONS OF POLLEN GERMINATION IN FLAX

By L. N. KOKHANOVSKAYA

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In the summer 1938, in course of the work carried on at the Physiological Laboratory of the Institute of Plant Industry it was found necessary to test the germinating capacity of flax pollen. However, all attempts to germinate it artificially by the usual method, i. e., in saccharose solutions of various concentrations (from 0.1 *n* to 2.0 *n*) on 1%, 1.5%, or 2% agar or on 10% gelatin, proved a failure. With a concentration of saccharose below 2 *n* the pollen grains burst at once, while in a 2 *n* solution of saccharose they did not burst, neither did they germinate. In the case of higher concentrations they decreased in volume becoming shriveled.

What are the most favourable conditions for germinating flax pollen in vitro? What are the optimum conditions for its germination on the stigma? Germination under natural conditions undoubtedly differs greatly from that in vitro. Germination on stigmas which separate no secretion (which is the case in flax) cannot be compared with germination in culture drop. Such stigmas are in contact only with a small part of the surface of a pollen grain. The remaining part of the pollen grain is surrounded by more or less humid atmosphere.

The present investigation aimed to: (1) find out the most favourable conditions for the germination of flax pollen; (2) to find out the most favourable conditions for the growth of the pollen tubes; and (3) to compare the results obtained with the physiological phenomena observed in the tissues of the pistil. In the present paper we report the results of experiments conducted in 1938, mainly on the problems involved in the first part of our work.

In our experiments we used pollen from flax of the following varieties: «DS 33» (Institute of Plant Industry), «Kuibyshev» (an intermediate-type flax), large-seeded flax (from Egypt), Abyssinian flax, and *Linum usitatissimum* (L.) Vav. consp. nov. ssp. *indo-abyssinicum* var. *albidum*. The pollen of each variety was taken at the same stage of maturity from plants grown under identical conditions*.

We used a modification of Renner's culture-drop method placing the pollen not in a drop of water or solution but in close proximity to the drop. In our experiments there was placed on the middle of a cover glass a small, flat drop of substratum of 10% gelatin or 1%, 1.5% or 2% agar. On this

* The pollen of varieties «DS 33» and «Kuibyshev» was obtained from the experimental field of the Laboratory Crops of the Institute of Plant Industry, that of the other varieties from the green-house of the Department of Plant Geography of the same Institute.

drop of substratum, after it had become dried, we placed pollen, carefully shaking it off a laboratory needle or pin scalpel, and beside it we placed a few small drops of a solution of chemically pure saccharose of a definite concentration (0.1 *n*—2.0 *n*), in such a way that the substratum and the fluid did not come into contact.

After placing the pollen in this manner on a cover glass, the latter was inverted and sealed with vaseline to the glass ring (inner diameter of the ring—15 mm; height—5 mm) of a moist chamber. The saccharose solution used was changed every 2—3 days by diluting the initial solution. The initial solution (2 *n*) is stable, so that it may be used for about 18 days. The chambers with the cultures were kept on the work table, on which the microscopic investigation was afterwards made, in a room facing north, the maximum variation in temperature not exceeding 1.5° C.

In a moist chamber a definite humidity is soon established, and the substratum begins gradually to swell. If—like gelatin, for instance—it is not absorbent, its surface does not become covered with free drops of moisture. By using this method the pollen grains gradually absorb the water necessary for germination. The moisture in such a case might be obtained either from the swollen substratum or in the form of vapour from the humid atmosphere. In order to decide this question, experiments were conducted on germinating flax pollen without a substratum. Pollen placed on a cover glass next to a 1 *n* solution of saccharose did not germinate. Occasional pollen grains germinated next to 0.7, 1, 1.6 and 2 *n* solution of saccharose near a dried drop of gelatin, the growth of the pollen tubes proceeding very slowly.

Experiments on Germinating Flax Pollen on a Dried Drop of Agar. Pollen grains placed on 1% agar next to a 0.1—1*n* solution of saccharose germinated with all of the concentrations tested. When placed next to a 0.1 *n* solution of saccharose, the pollen grains began to swell immediately after sowing and germinated within 5 minutes, but the pollen tubes burst before their length had attained that of a pollen grain. About the same held true in the case of higher concentrations of saccharose up to the normal solution. Pollen grains placed next to a normal solution of saccharose began to germinate 25 minutes after sowing, and their germination proceeded rather uniformly. The most rapid germination and the most rapid growth of pollen tubes in a great number of pollen grains were found to occur, when the grains were placed near the edge of a dried drop of agar, especially when placed not singly but in groups—observation first made by Brink ([8]). This confirms the opinion expressed by Kuhn ([4]) as to the importance of the thickness of the substratum in connexion with various concentration of the substances inducing pollen-tube growth.

When sown on 1.5% agar, the pollen grains germinated most uniformly and developed the longest tubes if placed next to a 1.7 *n* saccharose solution. When sown on 2% agar, germination was best if the grains were placed next to a 1.8 *n* solution of saccharose (Fig. 1). The pollen tubes then attained a length of 240 μ. They did not burst even 24 hours after sowing. They perished owing to the condensation of water on the surface of the agar.

Experiments on Germinating Flax Pollen on a Dried Drop of 10% Gelatin. On 10% gelatin flax pollen germinates somewhat less uniformly, but the pollen tubes do not burst as soon as on agar. Germination usually began 10—15 minutes after sowing next to saccharose solutions of various concentrations—from 0.1 *n* to 2.0 *n*. The longest pollen tubes (200 μ) were observed when the grains were placed next to a 1.4 *n* solution of saccharose, while they were shorter when placed next to a 1.3*n*, 1.6 *n* and 1.7 *n* solution (Fig. 2). Next to a 1.8 *n* or 1.9 *n* solution

only occasional pollen grains germinated, while next to a 2 *n* solution germination was not observed at all.

The experiments described above were made, for the most part, with *albidum* pollen in May and June, 1938, at a temperature of 16—17° C.

A similar series of experiments were made in July, 1938, with pollen of the varieties «DS 33» and «Kuibyshev» at a temperature of 20—24.5° C. In these experiments pollen of the variety «DS 33» swelled almost instantaneously when placed next to a 0.1 *n* solution of saccharose, and began to germinate 10—15 mitutes after sowing, but after another 5 minutes they began to burst. Thirty minutes after sowing most of the germinated pollen grains had burst. When placed next to a 1.3 *n* or 1.4 *n* saccharose solution, the pollen tubes burst before they had even attained the length of the diameter of a pollen grain. When placed next to a 1 *n* solution (34%) of saccharose, «Kuibyshev» pollen begins to germinate 20 minutes after sowing (65—75% germination), but immediately bursts. When sown on 10% gelatin next to a 1.9 *n*

Fig. 1. Growth of pollen tubes of flax from Egypt on a dried drop of 2% agar, next to a 1.8 *n* saccharose solution; 6 hours after sowing.

Fig. 2. Growth of pollen tubes of *albidum* flax on a dried drop of 10% gelatin, next to a 1.4 *n* saccharose solution; 30 minutes after sowing.

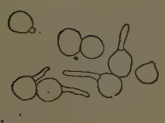

Fig. 3. Growth of pollen tubes of «Kuibyshev» flax on 10% gelatin, next to a 1.9 *n* saccharose solution; 30 minutes after sowing.

Fig. 4. Growth of pollen tubes of «Kuibyshev» flax on 10% gelatin, next to a 2 *n* saccharose solution; 30 minutes after sowing.

Fig. 5. Growth of pollen tubes of *albidum* flax on a dried drop of 10% gelatin, next to a 1.5 *n* saccharose solution, with the addition of heteroauxine to the substratum; 1½ hours after sowing

saccharose solution, this pollen began to germinate 30 minutes after sowing. An hour after sowing the pollen tubes had attained a length of 20 μ, but in another 10 minutes they burst. (It should be recalled that next to a 1.9 *n* saccharose solution *albidum* pollen in the preceding series of experiments did not germinate at all). When sown next to a 2 *n* saccharose solution, some of the pollen grains germinated, but 30 minutes after sowing they began to burst. Thus, *albidum* pollen did not germinate next to a 1.9 *n* saccharose solution, while «Kuibyshev» pollen germinated even next to a 2 *n* solution. However, in the latter case the percentage of germination is low, and the pollen tubes are abnormally thickened and soon cease growth (Figs. 3 and 4).

The observed variations in the ability of pollen grains to germinate as well as the differences in length of the pollen tubes may be ascribed to: (1) the higher atmospheric temperature (24.5° C) at which the germination of «Kuibyshev» pollen was tested, as compared with the temperature (16°—17° C) at which the germination of the *albidum* pollen was tested; (2) the fact that «Kuibyshev» and *albidum* flax belong to different ecological groups;

and, which is very important, (3) differences in the pH of the culture medium. As has been shown by works of Gotoh [9], Brink [10], and von Berg [11], the pH of the medium is in a number of species of decisive importance in the germination of pollen and the growth of pollen tubes.

Thus, with the aid of the method described we succeeded in germinating flax pollen. However, under the conditions of our experiment the growth of the pollen tubes did not proceed sufficiently well. The greatest length attained by flax pollen tubes in our experiment was 240 μ. Under natural conditions, as is well known, flax pollen tubes must pass a considerably greater distance through the tissues of the style in order to reach the ovules.

In order to create more favourable conditions for the growth of the pollen tubes we made, among other experiments, one on germinating the pollen on 10% gelatin with the addition of β-indol-acetic acid (5 mg per 100 cm^3 of distilled water). The effect of this heteroauxine was manifest only in a slight increase in the length of the pollen tubes (Fig. 5).

The elucidation of the conditions under which pollen tubes grow in the pistil, of the growth substances present in the pollen tubes and pistils and also of the osmotic interrelations between the pollen tubes and the tissues of the pistil will help us in the solution of the problems of self-sterility, of the development of sexual isolation as between polyploids and their initial diploid types, and of other general problems of the physiology of fertilization.

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PLANT PHYSIOLOGY

STORING OF CARBOHYDRATES BY FORAGE-GRASSES

By A. S. MOROSOV

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The question as to the conversion and storing of carbohydrates by various meadow-crops is of exceptional interest and importance. While studying it not only has the amount of some or other sugar to be estimated, but its relation, as well as that of other carbohydrates, to the age and development of the plant should also be traced. The vegetative parts of a forage-grass, i. e., its stems and leaves, are stored with important amounts of hemicellulose, pentosanes, starch and cellulose. There is a great accumulation of literature on the carbohydrate metabolism in higher plants, and the statement that carbohydrates are the first products of photosynthesis dates as far back as to the times of J. Sachs (1). New data on carbohydrate photosynthesis have been reported by F. Krasheninnikov (2). The formation of carbohydrates in the leaves is attended by their intensive migration to the stems, shortened internodes, roots and rootstocks. Such depositaries of reserve carbohydrates in meadow-crops are usually the roots, rootstocks and bulbs. The timothy has been reported by Smelov (3) to store reserve matter during a definite phase of its development, which in the case of cultivated form of this plant falls within the period from heading till full flowering and the outset of fruiting.

The present investigation has involved the *Bromus inermis* Leyss., the *Lolium perenne*, the *Festuca pratense* and some other grasses. The material for the experiment was prepared as follows. The plants were freed from the soil and leaves, stems, shortened internodes, roots and rhizomes were severed from them. The material thus obtained was killed by keeping it at 100—102° C during 15 minutes and then dried at 50—60° C. When dry it was ground in a mortar, sifted thinly and placed into tightly closed test-tubes. The severed parts were analyzed separately. The carbohydrates were estimated according to the plan of Kiesel (4), the sugars, according to Bertrand. The figures obtained and recalculated for 1 g of dry matter, are referred to in the following tables. In Table 1 we see the carbohydrates to be stored by the leaves. And in all cases we find the sucrose to exceed the monosaccharides. The higher the amount of sucrose, the greater is the total of carbohydrates. We find also the plants to increase in carbohydrates as they grow and develop, and to attain the maximum content at the phase of flowering. At the time of fruiting a slight decrease is observed to take place.

In the stems the total of carbohydrates is much higher during than after and before flowering. Any pronounced depression in the storing of carbohydrates was not observed in the various phenological phases. During flow-

Table 1

Storing of Carbohydrates by the Leaves of Various Grasses (in % of dry weight)

Crop	Phase of development	Monosaccharides	Sucrose	Inuline-like substances	Hemicellulose	Total of carbohydrates
1. *Bromus inermis* Leyss.	Tillering	0.25	2.12	19.22	7.00	28.59
	Flowering	0.23	2.09	20.43	20.90	43.65
	Fruiting	0.14	2.10	3.50	10.07	15.81
2. *Lolium perenne*	Tillering	1.20	2.27	25.00	10.15	37.62
	Flowering	1.10	5.95	17.36	12.05	36.46
	Fruiting	0.95	1.65	2.50	1.65	6.75
3. *Festuca pratense*	Tillering	0.21	1.57	14.21	6.12	22.11
	Flowering	1.55	9.55	10.24	6.55	27.89
	Fruiting	0.12	1.70	2.95	5.70	10.47

ering the store of carbohydrates in the stems is largely taken up by inuline-like substances and the hemicellulose, which appear therefore to constitute its principal basis.

The results are summarized in Table 2.

Table 2

Storing of Carbohydrates by the Stems of Various Grasses

Crop	Phase of development	Monosaccharides	Sucrose	Inuline-like substances	Hemicellulose	Total of carbohydrates
1. *Bromus inermis* Leyss.	Tillering	0.25	2.12	19.22	7.00	28.59
	Flowering	0.18	2.63	23.10	16.30	42.21
	Fruiting	0.15	3.03	21.90	12.32	37.40
2. *Lolium perenne*	Tillering	0.20	2.27	25.00	10.15	37.62
	Flowering	2.10	3.65	31.45	12.35	49.55
	Fruiting	0.18	2.57	24.38	16.32	43.45
3. *Festuca pratense*	Tillering	0.21	1.57	14.32	6.12	22.22
	Flowering	0.37	1.66	16.18	6.12	24.33
	Fruiting	0.29	2.26	11.34	5.70	19.59

In the shortened internodes the increase in sucrose is attended by considerable increase in the inuline-like substances and hemicellulose. This relation is especially conspicuous during flowering and fruiting.

The data on the internodes are given in Table 3.

In the roots and rhizomes of *Bromus inermis* Leyss. The total of carbohydrates is a maximum at the time of fruiting when it is largely taken up by the inuline-like substances and hemicellulose. The other crops tested show a slight decline in their content of carbohydrates at that time.

Table 3

Storing of Carbohydrates by the Shortened Internodes of Various Grasses

Crop	Phase of development	Monosaccharides	Sucrose	Inuline-like substances	Hemicellulose	Total of carbohydrates
1. *Bromus inermis* Leyss.	Tillering	0.11	1.33	11.39	11.80	24.63
	Flowering	0.17	2.90	25.17	16.70	44.94
	Fruiting	0.11	1.52	16.80	14.10	32.53
2. *Lolium perenne*	Tillering	0.16	0.73	8.60	12.60	22.09
	Flowering	1.10	1.32	14.13	17.67	34.22
	Fruiting	0.17	1.24	11.34	18.22	30.97
3. *Festuca pratense*	Tillering	0.95	0.67	7.38	11.55	20.15
	Flowering	1.40	6.15	8.34	9.65	25.54
	Fruiting	0.86	1.52	16.14	10.15	28.67

Table 4

Storing of Carbohydrates by the Roots and Rhizomes of Various Grasses

Crop	Phase of development	Monosaccharides	Sucrose	Inuline-like substances	Hemicellulose	Total of carbohydrates
1. *Bromus inermis* Leyss.	Tillering	0.50	1.48	15.23	9.65	26.86
	Flowering	0.12	1.17	12.29	14.40	27.98
	Fruiting	0.14	1.02	11.60	19.65	32.41
2. *Lolium perenne*	Tillering	0.12	0.45	5.70	14.90	21.17
	Flowering	0.75	5.00	6.31	13.50	25.56
	Fruiting	0.11	0.48	4.37	13.70	18.66
3. *Festuca pratense*	Tillering	0.95	0.67	5.18	11.15	17.95
	Flowering	1.25	5.15	6.37	7.32	20.09
	Fruiting	0.75	0.74	8.15	7.57	17.21

The conclusions to be drawn from the results obtained are as follows.

1. The seats of carbohydrate accumulation in forage-grasses are roots, rhizomes, stems, shortened internodes and leaves. The carbohydrates stored are chiefly inuline-like substances and hemicellulose.

2. The sucrose is always predominating over the monosaccharides and its increase is attended by an increase in the total content of carbohydrates.

3. The carbohydrate content goes up as the plant grows and develops and attains a maximum when it flowers.

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MICROBIOLOGY

FURTHER STUDIES ON THE PHENOMENON OF AUTOMYCOPHAGY

By V. F. ALTERGOT

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We were the first to describe jointly with Werner (3) the phenomenon of spontaneous lysis occurring in pure cultures of species belonging to the genus *Fusarium*. The study of the micro- and macroscopic appearance of this lysis, of the conditions provoking it, of the genesis of the lysing principle has led us to the conviction that these phenomena of autodissolution are connected with a disturbance of the mutual relation between the destructive and formative processes during the reproduction of the organism, this disturbance being caused by factors of the surrounding medium and leading to a complete destruction of the organism. The resemblance of this phenomenon to the lysis of the bacterial cell in bacteriophagy permits, contrary to the interpretation given to this phenomenon by d'Herelle (10), to consider the lysis of the organism of these fungi as a particular phenomenon to which we have given the name of automycophagy.

The present study is to confirm and develop the statement previously advanced by us.

The organisms of bacteria and fungi excel all other organisms in their extraordinary rate of growth and development. The internal regrouping of their constitutional substances must proceed most intensely. The relative simplicity of organization and the absense of a profound differentiation of the cell make the phenomenon of a speedy and complete autodissolution of these organisms, when the normal correlation of the processes of formation and destruction of the plasm complex is disturbed in the course of growth phenomena, easy to understand. Our data (3) show that the lysis of the fungus demands more time than that of the bacterial cell, the explanation of this lying in its more complex structure. Moreover, it has been earlier demonstrated by us (3) and corroborated later by Krassilnikov (8,9) for the *Actinomyce tales* that this lysis is determined by the character of the medium.

Considering the high sensitivity of *Fusarium* to the presence of *B*-substances of growth in the medium (2), it was but natural to assume that high concentrations of these substances should markedly disturb the above correlations and provoke the autodissolution of the organism.

Sterilized liquid Richard's medium in 150 cm³ Erlenmeyer flasks was seeded with 1 cm³ of a suspension of *Fusarium niveum* Smith or *Fusarium lini* Bolley spores. Yeast bios in concentrations of 0.1, 1 and 5 p. c. was added to the contents of the test flasks. Cultivation proceeded in an incubator

at 28°C. Macro- and microscopic examination was done during one month. The results are summarized in Table 1.

Table 1

Species of *Fusarium*	Bios content in medium (p. c.)	Interval between seeding and beginning of growth		Rate of growth	Interval between seeding and beginning of macro- and microlysis	Microscopic picture of lysis
		Immersed mycelium	Superficial mycelium			
Fusarium niveun Smith	Without bios	On the 2nd day	On the 6th day	+	On the 13th day	Abundant granular cells appear. No spores.
Do	0.1	On the 2nd day	On the 4th day	++	On the 9th day	Abundant granularity in every cell. The tips of cells show pear-like swellings. Granularities outside of cells. Spores are encountered.
»	1.0	On the 2nd day	On the 2nd day	++	On the 7th day	Abundant empty cells. Granularities without them. Abundant spores.
»	5 0	On the 2nd day	On the 2nd day	+++	On the 5th day	Fragments of empty hyphae. Numerous spores.
Fusarium lini Bolley	Without bios	On the 2nd day	On the 7th day	+	On the 15th day	Picture analogous to the one obtained with *Fusarium niveum* Smith.
Do	0.1	On the 2nd day	On the 5th day	+	On the 11th day	
»	1.0	On the 2nd day	On the 3rd day	+++	On the 9th day	
»	5.0	On the 2nd day	On the 2nd day	+++	On the 7th day	

These results confirm our expectations. The formation of the surface film, the rate of growth, the accumulation of the total mass of mycelium run parallel to the content of *B*-substances of growth in the medium, while their higher concentration provokes rapid lysis.

In the light of our views on the disturbance of the correlation between the formative and destructive processes as causing autodissolution, it should be expected that every external factor which acts in the opposite direction, inhibiting or merely delaying the processes of growth ought to lead to lysis, like those factors which stimulate growth. The experiments were run in two variants. A relatively lyse-resistant strain, *Fusarium niveum* IV, was inoculated into the centre of Petri dishes with the agar-containing Waksman medium. In the first variant the dishes were placed in a moist chamber and incubated at 28°C until the colonies reached the size of 3—4 cm in diameter, after which one part of the dishes was transferred to another incubator, with a temperature of 40°C. In the second variant the dishes immediately after inoculation were incubated at one or other of these two temperatures, 28° or 40° C. In the first variant growth was stopped already on the 2nd day at 40° C. On the 8th day, the colonies of the control dishes (28°)

cover almost the entire surface; the mycelium is fluffy. In the test dishes (40°) the diameter of the colonies has increased only by 0.5 cm; 2—3 foci of lysis are observed within the colonies. The microscopic examination of material taken from these foci shows complete destruction: fragments of hyphae with vague outlines, abundant granularity. By the 15th day we observe in the controls a normal growth, in the test cultures—complete mucification, the diameter increase is insignificant, the colony breaks easily at the touch of the loop. Under the microscope we see pear-like, swollen vacuolized cells; an abundance of hyphae fragments and granularity. The results of the second variant are identical. The only difference is that, while in the control (initial temperature 28° C) the colony covers the entire surface of the dish with a fluffy mycelium by the 10th day, in the test (initial temperature 40° C) the colony reaches only about 2 cm in diameter and shows marked mucification from the very beginning of growth, every symptom of profound lysis being visible under the microscope. It should be noted that in both variants the test cultures, in spite of the lysis, did not lose their viability, to judge by the diameter increase of the colonies and the presence of growth in transfers.

These experiments confirmed our expectations: supraoptimal temperatures, being a factor which hinders the processes of growth, provoke lysis. The provocation and acceleration of lysis by high temperature have been confirmed by Krassilnikov and Koreniako ([9]) for the *Actinomycetales*.

A comparison of the influence of *B*-substances of growth on the setting in of the lysis with the results of our earlier ([3]) investigation on the effect of filtrates from lysing cultures on the lysis of normal *Fusarium* mycelium makes it possible to discover an analogy between both. Experiments were arranged in two variants: 1—filtrates from lysing cultures and *B*-substances are introduced into Richard's agar or liquid medium before inoculation, and even before sterilization; 2—the same stimulants are introduced into the organism growing on Richard's solid medium, after the mycelium has already reached sufficient development, by moistening small clods of sterile sand, which are distributed over the surface of the mycelium. The filtrates were obtained from *Fusarium niveum* and *Fusarium lini* cultures, which had lysed at 28° C or 40 ° C in Richard's liquid medium, by filtering off the remains of the destroyed mycelium. In the 1st variant the filtrates were sterilized together with the medium at a pressure 1 atm. for 20 minutes; in the 2nd they were sterilized separately. As the results were similar in both cases we give below (Table 2) only a part of the results obtained in the 1st variant for *Fusarium niveum* Smith IV on a solid medium.

Table 2 shows that there is a great analogy between the action of high concentrations of the *B*-substances of growth and that of the lysing principle. Under the action of the latter lysis begins earlier and is more profound. The lysing factor is bound with the plasm complex; it is liberated by the depressing action of supraoptimal temperatures and accumulates in the medium, accelerating the lysis. The close relation of the *B*-substances of growth to the intracellular complex is pointed out by K. Sukhorukov, E. Kling and D. Kliachko ([13]), by K. Sukhorukov and Epel-Bogoslovkaya([14]), and more recently by J. Dagys ([6]).

The similarity of the nature of the lysing factor to that of the *B*-substances of growth has been checked with the help of the biological response of the yeast organism which, as this is known, responds readily to the presence of biocatalyzers in the medium([5]). A suspension of *Saccharomyces cerevisiae*, race XII was introduced into 20 cm^3 of sterile Hayduk medium [in which asparagin was substituted by $(NH_4)_2SO_4$]. Cultivation at 28° C. The sensitivity of the yeasts towards the stimulator was raised by 6 consecutive transfers

Table 2

Test object	Stimulant	Amount of stimulant (p. c.)	Interval between seeding and beginning of macroscopic growth	Rate of growth	Interval between seeding and beginning of lysis	Character of lysis of the colonies
Fusarium niveum Smith	Control	—	On the 2nd day	+	On the 15th day	An almost unnoticeable lysis, beginning with the adhering of the mycelium to the medium
»	Bios	0.1	On the 1st day	+	» 13 »	Adhering of mycelium; expanding leathery border of the colony
»	»	1.0	Do	++	» 10 »	Marked mucifying of colony from the periphery.
»	»	5.0	»	+++	» 7 »	Lysis from the periphery; later on leathery spots in the central part of the colony.
»	»	10.0	»	+++	» 5 »	Complete mucifying of colony from the very beginning of growth.
»	Filtrate from cultures lysed at 28°C	0.1	»	+	» 13 »	Adhering of mycelium, no mucifying.
»	»	1.0	»	+++	» 10 »	Adherence of mycelium: later on leathery quickly growing spots in the middle.
»	»	5.0	»	+++	» 10 »	Mycelium adhering is speedily mucified by the 5th day.
»	»	10.0	»	+++	» 10 »	
»	Filtrate from culture lysed at 40° C	0.1	»	+	» 4 »	Colonies in every dish are mucous from the very beginning.
		1.0	»	++	» 4 »	
		5.0	»	+++	» 3 »	Evident lysis everywhere, showing deep destruction of hyphae by the 3d—4th day.
		10.0	»	+++	» 3 »	

into the same medium (4). A sharp decrease of growth indicated the impoverishment of the cells in respect of *B*-substances. A suspension of a definite cell concentration of the thus obtained «starving» yeasts was inoculated into Hayduk's medium to which previous to sterilization varying concentrations of the filtrate from lysing (at 40° C) cultures of *Fusarium niveum* and *Fusarium lini* on Richard's medium were added. As a second control

Table 3

Number of cells per 1 cm³ / Medium	Control				Lysing factor																			
	1*	2**	3***	4****	0.05				0.1				1.0				3.0				5.0			
					1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Hayduk	7	133	126	1800	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hayduk+ +Richard	—	—	—	—	7	154	147	2100	—	—	—	—	7	155	148	2114	7	156	149	2128	7	202	195	2785
Hayduk+ Richard+ filtrate from *Fusarium lini*	—	—	—	—	7	210	203	2900	7	467	460	6571	7	734	727	10 385	7	827	820	11 714	7	840	833	11 900
Hayduk+ Richard+ filtrate from *Fusarium niveum* IV	—	—	—	—	7	331	324	4628	7	310	303	4328	7	568	561	8014	7	816	809	11 557	7	965	958	13 685

* Initial number of cells

** Final number of cells 2 days after inoculation

*** Absolute increment

**** Percentage of increase

we introduced a variant to which we added Richard's medium. The cells were counted in Thoma-Zeiss chamber. The data on the increment are summarized in Table 3.

The data of Table 3 permit to suppose that there exists a fargoing analogy in the nature of the substances compared.

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